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**An evaluation of tall fescue (*Lolium arundinaceum*) as an  
alternative to perennial ryegrass (*Lolium perenne*) for use on  
dairy farms in the Waikato.**

A thesis

submitted in partial fulfilment

of the requirements for the degree of

**Master of Science in Biological Sciences**

at

**The University of Waikato**

by

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THE UNIVERSITY OF  
**WAIKATO**  
*Te Whare Wānanga o Waikato*

The University of Waikato

2011



## ABSTRACT

Grazed pasture provides the bulk of feed on New Zealand dairy farms. As such, the amount, and the nutritive value, of the pasture grown directly influences farm production and profitability. In the Waikato (North Island, New Zealand), low soil moisture is a major constraint to pasture production and recent droughts have highlighted the limitations of the predominant pasture species, perennial ryegrass (*Lolium perenne*), in this region. Methods of mitigating the effects of low soil moisture include the use of drought tolerant species, like tall fescue (*Lolium arundinaceum*), and by using irrigation.

The main objectives of this research were to compare the pasture dry matter (DM) production, nutritive value and survival of two tall fescue types (Continental, CTF; and Mediterranean, MTF) with perennial ryegrass (PR). Pastures were sown as either a grass monoculture or as grass-dominant mixtures with either white clover (*Trifolium repens*), red clover (*Trifolium pratense*) or chicory (*Cichorium intybus*) as companion species. The experimental design was a split block with two identical small plot experiments that were either fully irrigated (I+) or were not irrigated (I-) and were rotationally grazed by dairy cows. One experiment was established in autumn 2007 and spanned one year. A second experiment was established in spring 2008 that spanned two years, in order to determine whether productive pastures of tall fescue can be established in both seasons.

Annual DM yields of I+PR pastures averaged 16.9 t DM/ha across the 3 years evaluated in this study. This was consistently greater ( $P < 0.003$ ) than either I+CTF or I+MTF pastures (averaging 13.7 and 12.5 t DM/ha, respectively). Average I- DM yields were more similar at 14.5, 13.6 and 12.8 t DM/ha from I-PR, I-CTF and I-MTF pastures, respectively. Generally, PR pastures produced superior seasonal DM yields than CTF or MTF pastures, with three exceptions. In summer 2007/2008 both I+ and I-CTF pastures produced 0.6 and 1.5 t DM/ha more ( $P = 0.004$ ) DM than I+ and I-PR pastures, respectively. Also, in winter ( $P < 0.001$ ) and spring 2009 ( $P = 0.003$ ) I-CTF pastures produced more DM than I-PR, however, at these times an irrigation interaction was observed ( $P < 0.001$ ) where I+PR produced more DM than I+CTF. The enhanced I-CTF production was associated with higher tiller densities observed on I-CTF relative to I+CTF

pastures that were likely a result of reduced competition from companion and weed species under low soil moisture.

Irrigation enhanced annual DM yield of PR pastures (range 2 – 37%). While the effect of irrigation on yields of CTF and MTF was variable, ranging from a negative response (-23%) to a 16% increase, that was likely influenced by the companion species and weed content of the pastures.

The addition of a companion species either reduced or produced equivalent DM yields to the monoculture pastures. While the companion species chicory contributed greatly to yield in the warmer months (December to April), this was commonly associated with a decline of sown grass yield and tiller density.

Nutritive value, as defined by metabolisable energy (ME) content of herbage, from PR pastures (mean 13.0 MJ ME/kg DM) was greater than from those based on tall fescue pastures (mean 12.3 MJ ME/kg DM). However, crude protein (CP) content was greater on the CTF and MTF pastures (mean 23.9%) than the PR pastures (mean 21.5%), including the monoculture pastures (23.2 vs. 20.7% from tall fescue and PR respectively), indicating that CTF and MTF plants contain higher CP than PR plants. The ME content was largely unaffected by companion species, and the effect on CP was variable, though when differences were observed they were the result of increased CP content on the mixed pastures relative to the pasture monocultures.

The magnitude of PR loss during drought was 7.5 times greater than observed on the CTF and MTF pastures. Where the decline in tiller density from I-PR pastures was 2280 tillers/m<sup>2</sup>, compared to a loss of 300 tillers/m<sup>2</sup> from I-CTF pastures during the autumn 2009 drought, equating to a 46 and 16% reduction in tiller density from I-PR and I-CTF respectively. At both sowing times, sown grass establishment was similar. However, the less vigorous nature of the fescue seedlings allowed for higher levels of companion species in the sward relative to PR (32 vs. 13%, respectively). Although, by the end of each experiment the sown species in CTF and PR pastures dominated, signalling that both autumn and spring establishment of these pastures can be successful. The contribution of MTF to pastures was poor when sown with a companion species and by the end of the two year spring sown experiment averaged 16%, indicating poor survival.

These results suggest that perennial ryegrass-based pastures are more productive and of higher quality than those based on tall fescue both in irrigated and non-irrigated conditions under dairy cow grazing in the Waikato. However, the greater companion species content and CP levels of CTF pastures and enhanced production when soil moisture was low relative to PR indicates that CTF may have a role in terms of a specialist pasture species on farm. The poor survival and yields of MTF pastures indicate that this species is not suitable for use on dairy farms in the Waikato.



## ACKNOWLEDGEMENTS

Four years. At times this has sounded long (i.e. at the start) but more recently far too short. All along however, this has been a challenging and rewarding experience, but also a very valuable learning opportunity, for which I would like to extend my sincere gratitude to the following people and organisations:

Dave Clark and Errol Thom, thank you very much for allowing me this opportunity and for reviewing my (often lengthy) manuscripts – particularly your assistance with editing my “waffle”, insightful comments and drawing my attention back to what I call the “so what?” factor when I get side-tracked with statistical significances. Thank you also to Julia Lee for reviewing manuscripts. Dave, Errol and Julia, please know I greatly appreciated the rapid review of said manuscripts, your time and your effort. I have been most fortunate to have reviewers of such calibre, I have learnt a lot and believe the phrase ‘prior to’ has finally been worked out of my system.

I wish to acknowledge the Pastoral 21 program for the funding of this project and the DairyNZ Science Intern program for financial and FTE support for which I am very grateful.

Chrissen Gemmill my university supervisor, for your efforts to keep me on track with deadlines and reviewing manuscripts on a topic somewhat out of your usual area of interest. Thank you for being so approachable, for always making time to meet with me, and for graciously accepting the aforementioned manuscripts for review somewhat later than I imagine you would’ve liked!

A huge thank you to all the DairyNZ technicians, past and present. This has not been a small task, with some 3600 plots harvested and 2186 botanicals dissected (just to name a few measurements). Dee, Cathy, Derek, Vili, Ange, Tracy, Lucy, Adam, Jackie, Nivonne, Jamie, Kristina, Paul, Nicola, Lana, Kirsty and Jamie – I could not have done this without all your help with measurements and data collection. DairyNZ is blessed with a truly exceptional technical team.

Thank you to Mark Bryant, my manager, for support and the gentle reminders about prioritisation.

Thank you to Barbara Dow, for assistance in the statistical analysis of the data; and then for your patience in helping me to understand the results when what seemed to be a simple trial design turned out to be not so simple to analyse.

Lastly, but by no means least, Christiaan, thank you for your support and encouragement; for being my personal IT support, chef and groundskeeper – I have no excuse now. I could not have completed this without you, big love always.

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## LIST OF ABBREVIATIONS

a.i.	active ingredient
ANOVA	analysis of variance
AS	autumn sown
ASW	argentine stem weevil
av.	average
c.	circa
CO <sub>2</sub>	carbon dioxide
°C	degrees Celsius
cm	centimetre
Ch	chicory
CTF	Continental tall fescue
CP	crude protein
cv	cultivar
DNA	deoxyribonucleic acid
DM	dry matter
FV	feed value
g	gram
ha	hectare
h	hour
I+	irrigated
I-	non-irrigated
K	potassium
kg	kilograms
L	litre
MTF	Mediterranean tall fescue
MJ	mega joules

ME	metabolisable energy
MS	milk solids
mg	milligrams
ml	millilitre
mm	millimetre
NDF	neutral detergent fibre
N	nitrogen
n	number
NIRS	near Infrared Spectroscopy
NV	nutritive value
PR	perennial ryegrass
<i>pers comm.</i>	personal comment
P	phosphorous
RC	red clover
SED	standard error
SS	spring sown
t	tonne
WSC	water soluble carbohydrates
WC	white clover
vs	versus
y	year

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## **1 GENERAL INTRODUCTION**

The dairy industry in New Zealand is the largest contributor to agricultural exports, accounting for 27% of export earnings with a value of \$11 billion in 2008-2009 (Anon. 2009a). As a consequence dairying has a large impact on the New Zealand economy. Within New Zealand, the Waikato is a major dairying region, with this being the main agricultural activity in the area since the 1880's (McKinnon *et al.* 1997). In Waikato in 2004, dairy farming and processing provided the highest contribution to gross regional product at 10.1%; and was the second largest employer (8%) (Cameron and Bell 2009). Dairying in the Waikato continues to grow, accounting for the highest proportion (32%) of the national dairy herd in 2009, an increase in animal numbers of 4% from the previous year, producing a average of 97 500 kg of milksolids per farm (Anon. 2009b).

In 2005 the New Zealand dairy industry set a goal to increase farmer profit and create wealth for the New Zealand economy through a 50% gain in forage productivity and an increase in pasture feed quality by 2015 (Anon. 2005). Luxton (2005) estimated that increasing forage production by 3.6% per annum would be required to meet this goal; this is a large increase considering Hodgson (1989) reported little increase in forage dry matter (DM) production from ryegrass pastures over thirty years (1960-1990).

### **1.1 Pastoral dairy farming in the Waikato**

Pastures provide the bulk of the feed on dairy farms in the Waikato and the wider New Zealand. This is because grazed forage is the most cost effective means of producing milk (Dillon *et al.* 2005) in New Zealand, costing around 5 cents per kg DM compared with 29 cents for palm kernel extract (Hockings 2010).

The Waikato climate is warm-temperate (Charlton and Stewart 2006), with average air temperature of 13.8 °C and annual rainfall of 1156 mm (30 yr average, 1975-2004, recorded at AgResearch's Ruakura Meteorological Station). This climate allows for pasture growth for most of the year (Valentine and Kemp 2007) with usually mild levels of drought stress (Charlton and Stewart 2006). However, there are concerns about the possible impact of climate change, as the last decade

(2000 - 2009) has been the warmest on record (NIWA 2010) with drought events occurring in two of the last three years (summer 2007/2008 and autumn 2009).

The dominant forage grass is perennial ryegrass (*Lolium perenne* L.), commonly sown in mixtures with white clover (*Trifolium repens*) and grazed rotationally. The extensive use of perennial ryegrass-based pastures is because it is easy to establish, and can produce large amounts of highly digestible DM, is tolerant of grazing (Kemp *et al.* 2004) and is well understood as it has been the subject of a large body of scientific research. However recent droughts in the Waikato region have highlighted the limitations of perennial ryegrass based pastures.

## 1.2 Potential to increase forage production

Factors that influence forage production are climate, soil fertility, pasture species and management practices (McMeekan 1964). Soil fertility, pasture species and management can be manipulated through the use of fertiliser and farm practice. The ability to modify climate, however, is limited. Yet climate has the greatest affect on pasture production and persistence (Rawnsley *et al.* 2007). The main limitation of perennial ryegrass pastures is reduced production and persistence at high soil and ambient temperatures and low soil moisture (Waller and Sale 2001). In the dairy system, this can result in reduced feed supply leading to sub-optimal dietary intake which reduces milk production, accelerates the rate of decline in post peak milk yield (Exton *et al.* 1996) and can result in loss of animal condition.

Tall fescue (*Lolium arundinaceum* (Schreb.) Darbysh.; formerly classified as *Festuca arundinacea* Schreb.) has been shown to produce more annual and warm season forage DM than has perennial ryegrass (Judd *et al.* 1990; Milne *et al.* 1997; Rollo *et al.* 1998; Thomson *et al.* 1988). This advantage over ryegrass is likely due to greater drought and temperature tolerance of tall fescue (Hainsworth and Thomson 1997; Thorogood 2003). However, early cultivars of tall fescue available in New Zealand were difficult to establish, required different management strategies to ryegrass and were deemed to be of lower feed quality. These cultivars were also endophyte-free and were therefore susceptible to insect feeding which reduced pasture persistence. More recent varieties of tall fescue are purported to have enhanced establishment vigour and contain a non-toxic novel

endophyte that provides some protection against pasture pests (e.g. *Listronotus bonariensis*) (Popay *et al.* 2005).

Utilising irrigation is another means of mitigating low soil moisture. Currently only 14% of Waikato dairy farms use irrigation compared with the Canterbury region where 34% of dairy pastures are irrigated (MAF 2008). While irrigation usage has been shown to be of economic value (adding a farm gate value of around \$100, 000 to the Waikato, but \$175 million to the Canterbury region), water is a limited resource, best utilised by pasture species with high water use efficiency.

### **1.3 Aim and thesis structure**

The main aim of this thesis is to evaluate the forage dry matter production, nutritive quality and survival of tall fescue pastures under dairy cow grazing in the Waikato region of New Zealand.

The thesis is structured into five chapters. The general introduction (Chapter 1) is followed by a review of the literature pertaining to the production and quality of tall fescue pastures compared with perennial ryegrass pastures (Chapter 2). Chapter 3 examines the grass plant survival and species interactions in pure and mixed-species tall fescue-based pastures resulting from autumn and spring sowings. Chapter 4 examines the productivity and quality of autumn and spring sown tall fescue-based pastures with or without irrigation. Chapter 5 summarises the main findings of this research, the implications for dairy farming and possible directions of future research.



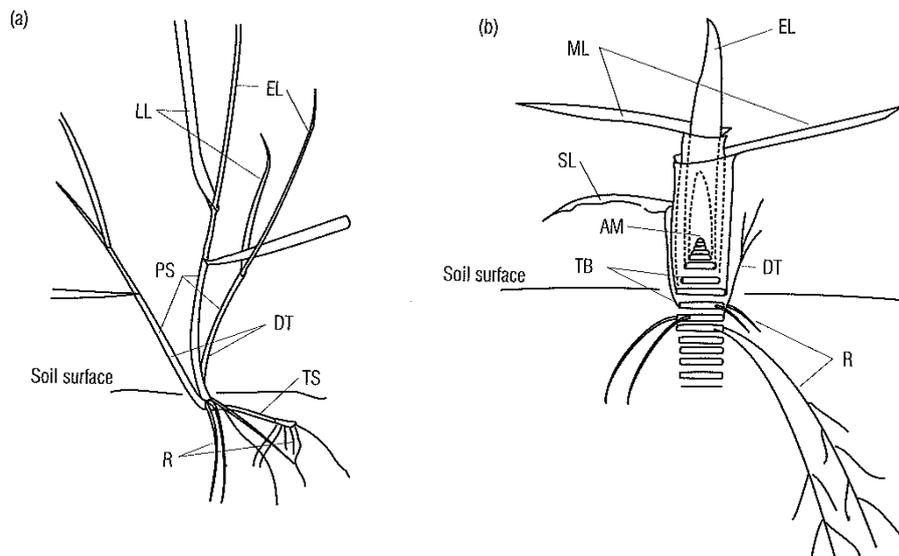
## 2 LITERATURE REVIEW

This review describes pasture production in New Zealand, and the factors that influence this. The advantages and limitations of the most common species in pastures in the Waikato, perennial ryegrass (*Lolium perenne* L.), are discussed in comparison to an alternative pasture species, tall fescue (*Lolium arundinaceum* (Schreb.) Darbysh.), that has potential for a use in Waikato dairy farm systems. Published research on the herbage production, forage quality and milk production from tall fescue pastures in relation to perennial ryegrass pastures is summarised.

### 2.1 Pasture

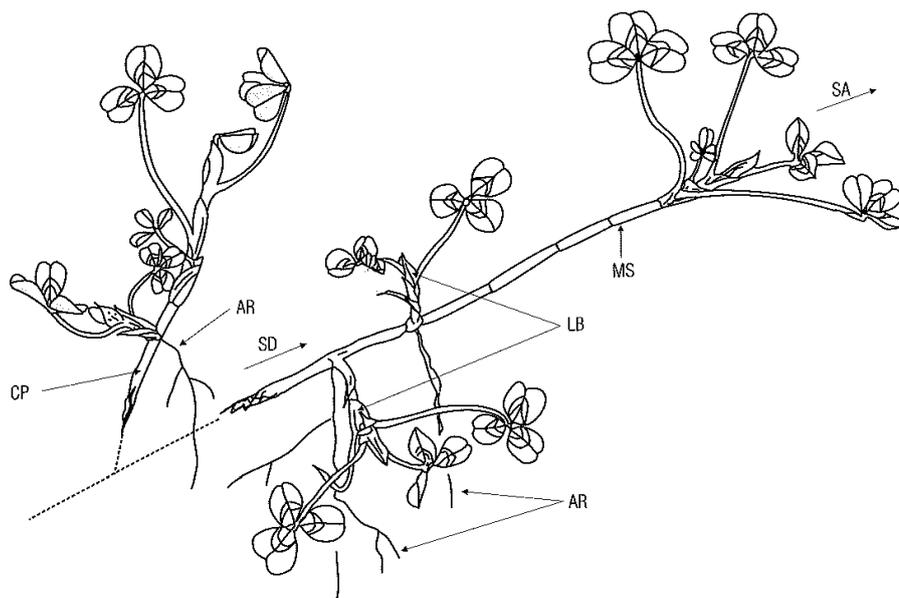
Charlton (2006) defined a pasture plant as one that can be defoliated (grazed) several times per year and continue to grow. The structure of the grass plant (family: Poaceae) has evolved to allow for this, where the plant is made up of a number of shoots, called tillers, that arise from an axillary bud within a leaf sheath. Tillers can develop their own root system to effectively become an independent plant, but are linked by nodal and intermodal tissue to comprise a tiller axis. The growing point (apical meristem) is located on top of the tiller axis and is commonly located near or below the soil surface, thus protected from grazing animals. Each tiller is made up of a series of segments, called phytomers that arise from the apical meristem to form either leaf, a daughter tiller, internode or stem. Grass phytomers have a life cycle, by which they age and die, and at the same time are replaced by new ones (Figure 2.1.). Thus pasture grass plants are continually forming new and shedding old leaves (Moot *et al.* 2007; Valentine and Matthew 2000). In this way, temperate pasture grasses reproduce both vegetatively as well as through sexual reproduction. The persistence and development of the pasture depends on the production of tillers. Tillers produced after reproductive growth in the spring form the basis of the plant population the following spring, as the life span of an individual tiller rarely exceeds 12 months (Gastal and Matthew 2005). Reproduction by seed is the main method of establishing new pastures but after this pastures can be maintained for several years primarily through vegetative reproduction. Seed develops in spring

(Charlton and Stewart 2006), though good management should seek to minimise this in dairy pastures (see section 2.1.2.5).



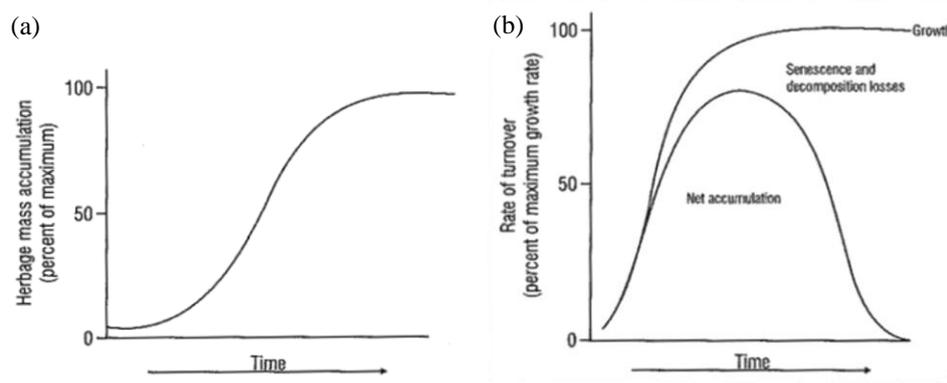
**Figure 2.1.** The morphology of a grass tiller: (a) organs visible externally and (b) showing arrangement of phytomers on the tiller axis (source: Valentine and Matthew 2000). AM = apical meristem, DT = daughter tiller, EL = elongating leaf, LL = leaf lamina, ML = mature leaf, PS = pseudostem composed of leaf sheaths, R = root, SL = senescent leaf, TB = axillary tiller bud, TS = true stem.

Another common pasture plant, white clover (*Trifolium repens* L.) (family: Fabaceae) also exhibits segmental morphology that allows for periodic defoliation. In the case of white clover, new phytomers are added to form leaves, branches, roots or to elongate the internode which is frequently termed a stolon. Stolons are laid down horizontally on the soil surface, extending at one end while old phytomers die and senesce at the other end (Figure 2.2). Leaves are held up horizontally by long petioles. Roots are formed at the nodes, thus if the stolon is broken or buried with soil due to animal treading the plant can continue growing independently (Valentine and Matthew 2000).



**Figure 2.2.** White clover plant morphology (source: Valentine and Matthew 2000). SA = stolon advance, MS = mature stolon, SD = stolon death, LB = lateral branch, CP = clonally propagated plantlet, AR = adventitious root.

The rate of growth of pasture after defoliation follows a S-shaped curve (Brougham 1957; Valentine and Matthew 2000) (Figure 2.3). As most of the photosynthetic leaf area is removed during defoliation growth rates are initially slow as the plant mobilises and utilises stored carbohydrate for growth (White 1973). As leaf develops, photosynthesis resumes and growth rate increases exponentially until maximum photosynthetic rate is reached and growth slows (Brougham 1957). If the pasture is left to mature beyond this net herbage accumulation declines as senescence and decomposition of the older leaves continues offsetting any growth (Moot *et al.* 2007; Valentine and Matthew 2000) (Figure 2.3).



**Figure 2.3.** (a) Pasture growth rate over time post defoliation (time = 0) and (b) showing net accumulation over time as a result of pasture growth and loss from senescence and decomposition (source: Valentine and Matthew 2000).

### 2.1.1 Pasture production in New Zealand

Pasture occupies 55% of agricultural land area in New Zealand, totalling over 8 million ha (Anon. 2009b), and provides the majority of feed supply on dairy farms (Holmes *et al.* 2007). Most farms supplement pasture with crops grown either on farm or imported to increase productivity, mitigate feed deficit or balance nutrients in the feed. Farm systems in New Zealand can be classified on a 1 – 5 scale defined by increasing proportion of supplementary feed imported on to the farm. System 1 farms are self contained with all feed produced on farm, where at the opposite end of the scale, a system 5 farm imports over 35% of the feed. The majority of Waikato dairy farms fit into systems 2 and 3 that are based primarily on pasture but import up to 14 and 20% of the feed respectively, to supplement dry cows and extend lactation in autumn (Headley and Kolver 2006), a time when pasture feed deficits can occur. Importing feed however, is more costly than producing pastures. Thus increasing DM from pastures on farm is economically advantageous.

Since the 1930s the most common dairy pastures sown in New Zealand and the Waikato is perennial ryegrass-based sown with white clover (Charlton and Stewart 1999). Thom (2000) noted that the reliance on one pasture type imposes a natural limit on dry matter production. Thus the inclusion of alternative forage species on farm, with differing adaptive ranges to climatic and biotic stresses may extend this limit.

In 1970 Cooper determined that potential yield from temperature pastures at mid latitude is 26.6 tonnes (t) of dry matter per hectare per year (t DM/ha/yr). Thom (2000) expanded on this suggesting that under conditions where light, water, temperature and nutrients are not limiting, potential pasture yield for the Waikato region is 24 t DM/ha/yr. However, these yields are rarely achieved in practice, with the average regional DM production for the Waikato currently between 12 and 17 t/ha/yr (Holmes *et al.* 2007). Limitations to pasture production are discussed below.

## **2.1.2 Factors affecting pasture production**

### *2.1.2.1 Light*

Light, as radiation, provides the energy for photosynthesis and therefore determines maximal photosynthetic response of a plant, within the bounds of genetic capabilities (McKenzie *et al.* 2000; Mitchell 1956). Thus the fastest plant growth occurs when light interception is maximal (Moot *et al.* 2007). Clark (2001) stated that New Zealand receives ample radiation for maximal growth. Yet the efficiency of radiation use by pasture plants is low, maximised at about 6% of incident photosynthetically active radiation (McKenzie *et al.* 2000). This is because other factors such as poor light interception, low soil moisture, nutrient stress, pest and disease pressure, extremes in temperature all limit photosynthesis (McKenzie *et al.* 2000; Moot *et al.* 2007).

There is a close relationship between light interception, leaf area and pasture growth, i.e. when leaf area is sufficient to capture maximum light energy, maximum growth rate is achieved (Korte and Sheath 1978). Leaf area available for intercepting light is in turn largely influenced by plant growth form in particular leaf size, tiller angle, leaf angle, leaf rigidity (Rhodes 1973). For example, the leaves of white clover are held horizontal on petioles and can be angled for maximal light interception (Valentine and Kemp 2007).

### *2.1.2.2 Temperature*

Both extreme cold and hot temperatures reduce photosynthesis leading to reduced shoot growth. Minimal growth occurs below 5°C and above 30°C (Berry and Bjorkman 1980; McKenzie *et al.* 2000; Mitchell 1956). Optimal ambient temperatures for shoot growth varies between pasture species, and furthermore

exhibit differing growth rates at differing temperatures (Gastal *et al.* 1992; Mitchell 1953; Peacock 1975; Woledge and Dennis 1982). Mitchell (1956) demonstrated that maximal percentage increase in shoot dry weight occurred at 20°C for perennial ryegrass (a C3 species<sup>1</sup>), but at 29.4°C for paspalum (*Paspalum dilatatum* Poir.; a C4 species). For temperate pasture species however, the range is usually within 20 – 25°C (McKenzie *et al.* 2000). Durand *et al.* (1999) showed that the time for one tall fescue (*Lolium arundinaceum*) leaf to fully extend took 42.5 days at a constant temperature of 24°C, but 51 days at 14°C.

Germination and emergence of seedlings is also correlated with temperature and varies between species. Moot *et al.* (2000) showed that the thermal time requirement for germination of herbage grass species was 93 and 120°C days for perennial ryegrass and tall fescue respectively, but only 41°C days for white clover. White clover also demonstrated a different temperature range for germination than perennial ryegrass, where germination of white clover seed was between 89 – 99% from 5-30°C, but germination of perennial ryegrass declined from 99% at 15°C to 70% at 25-30°C (Moot *et al.* 2000).

Soil temperature is also important as the main growing point of pasture grasses (meristematic centre) where new root and shoot material are formed is located near the soil surface (section 2.1), and root material is sensitive to temperature. Forbes *et al.* (1997) showed that only 16% of perennial ryegrass root material remained alive at a soil temperature of 27°C.

#### 2.1.2.3 Water

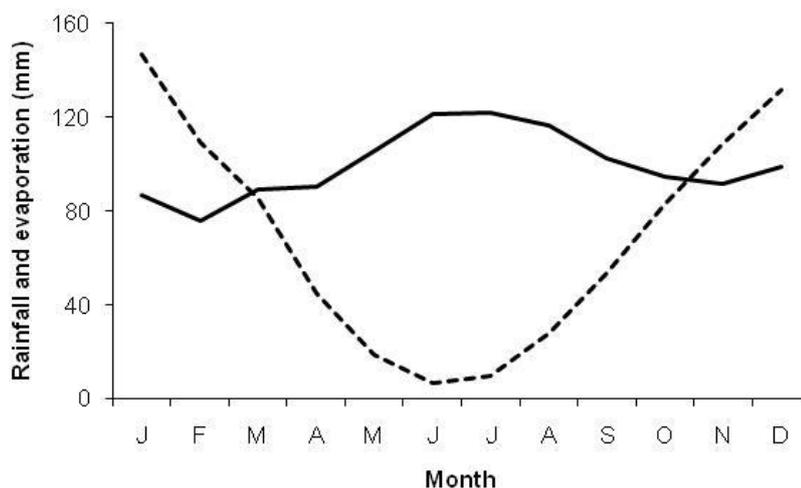
Soil moisture deficits are the primary limitation to pasture production in New Zealand (Corkill *et al.* 1980). Pasture plants are typically comprised of between 70-90% water, which is largely to provide structural support for cells. Most of the water taken up by the plant is transpired, which serves the function of transporting water and nutrients about the plant, and only a relatively small amount of water is used for photosynthesis. However as the rate of transpiration and photosynthesis are linked, when the plant encounters water stress they can reduce transpiration by

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<sup>1</sup> C3 species and C4 species differ in their biochemical mechanisms that fix carbon dioxide for photosynthesis.

closing the stomata but this also reduces the amount of carbon dioxide (CO<sub>2</sub>) absorbed thereby reducing photosynthesis (McKenzie *et al.* 2000). When water stress is severe enough plants can employ avoidance strategies such as dormancy where shoot growth and tiller formation is ceased while cell turgor is maintained at the meristem; however prolonged water deficit can result in plant death (Korte and Chu 1983).

For optimum production of pastures, approximately 1000 mm of rainfall evenly distributed throughout the year is required (Dillon *et al.* 2005). Average annual rainfall in the Waikato is 1150 mm (30 yr average 1975-2004, source: AgResearch Ruakura Meteorological Station) which is relatively evenly distributed; however, from November to March, evaporation can exceed rainfall (Clark *et al.* 2010) (Figure 2.4), leading to soil moisture deficit.



**Figure 2.4.** Average monthly rainfall, 30 year period (1975-2004) (solid line); and total potential evaporation, 5 year average (2005-2009) (dashed line) for the Waikato (source: AgResearch Climatological Station, Ruakura).

During this period (November to March) fluctuations in rainfall have the largest impact on both summer and annual pasture production (Corkill *et al.* 1980). Drought stress in the Waikato is usually mild (Charlton and Stewart 2006). However, the sporadic and unpredictable nature of drought, in terms of duration and intensity, poses risk of feed shortage at a critical time on the dairy farm (mid-lactation). The recent drought events in summer 2008 and autumn 2009, highlight the need for tools to manage this risk. To mitigate the impact of drought and

buffer seasonal fluctuations in water supply, farmers can utilise irrigation. Irrigation has allowed the expansion of dairy farming into the drier eastern areas of New Zealand, for example Canterbury where 350,000 ha are consented for irrigation (34% of which is on dairy farms) but it is also utilised in the Waikato. In 1999, estimated the area of land allocated for irrigation to be 4,500 ha, of which 14% was under dairy farming (Anon. 2009b). Irrigated land area has increased by 55% each decade in New Zealand (Lincoln Environmental 2000). Thom *et al.* (2001) investigated the effect of irrigation on perennial ryegrass pastures in the Waikato over four years and found that production was increased by 1 to 2 t DM/ha/yr under irrigation. This supports earlier work by Barker *et al.* (1998), also in the Waikato, where water deficit was observed to reduce perennial ryegrass pasture accumulation by 68% compared to irrigated pastures. Pasture plants suffering moisture stress also show decreased resistance to the pasture pests, grass grub and Argentine stem weevil (Charlton and Belgrave 1992).

#### 2.1.2.4 Nutrients

In high producing pasture based systems, deficiencies in mineral nutrients are a common limitation (McKenzie *et al.* 2000). New Zealand soils are naturally deficient in some of the major nutrients, such as: nitrogen (N) and phosphorous (P). Also, pastoral farming results in a loss of nutrients from the farm (i.e. N removed in the milk) (Kemp *et al.* 2000a). Deficiencies of these nutrients can be successfully remedied by the effective use of fertilisers, yet the environmental effect of fertiliser use must be taken into consideration (i.e. nitrate leaching).

Pasture grasses have a high demand for mineral N and consequently N deficiency is the most common nutrient deficiency in New Zealand soils. Nitrogen is required for the production of protein and chlorophyll; applications of N stimulate both root and shoot growth, therefore N is regularly used to boost herbage production (Brouwer 1966; Kemp *et al.* 2000a). Thom (2000) demonstrated that the use of 200 kg N/ha/yr increases total annual herbage production by 2 – 3 t DM/ha in the Waikato. However, Harris and Clark (1996) showed that N application at this rate depressed white clover content in pastures by 4 – 5%, which is counterproductive as white clover, a legume, fixes nitrogen in the soil reducing the need for N application by fertilisers. When legumes comprise 25 – 30% of the pasture, approximately 150 – 200 kg of N is fixed per year. However,

the magnitude of the plant response to N is determined by the level of other resources present, with greater responses observed under optimal light, temperature and soil moisture conditions (Whitehead 1995).

Phosphorous is a key nutrient required for photosynthesis, and is essential in the construction of cell membranes and DNA (Moot *et al.* 2007). In the early phase of seedling growth, P is required for the initial root development. A deficiency of P will result in the stunting of new leaf growth, and early senescence of older leaf material, reducing the overall productivity of the pasture (Moot *et al.* 2007).

#### 2.1.2.5 *Grazing management*

Mitchell (1966) stated that permanent pasture under intensive year round grazing, as in dairy farming situations, has never produced up to the potential that climate might allow and never can. Reasons for this include, potential damage to the plants growing points by animal treading and the difficulty in implementing ideal grazing management for optimal production.

The harvest interval, or length of time between defoliation events has a substantial effect of herbage growth. A grazing management approach must find a compromise between minimising the accumulation of senescent material and the defoliation of immature leaves (Clark *et al.* 2001; Moot *et al.* 2007). Herbage accumulation in pastures is the balance of the growth of new plant material and the senescence and decay of old plant material (Korte and Sheath 1978). Under infrequent defoliation (lax grazing) senescent material continues to accumulate, resulting in dry matter loss in the pasture. During the phase between defoliation events, pasture plants build up stores of water soluble carbohydrates (WSC) for use in subsequent regrowth post defoliation. Lee *et al.* (2008) showed that a considerable proportion of WSC (48%) are located in the bottom four centimetres of the tiller, consequently defoliation below this level reduced regrowth by 1130 kg DM/ha/yr compared to plants defoliated to a level of six centimetres, in a study evaluating defoliation intensity and severity on perennial ryegrass. Also, under too frequent defoliation, the plant may not have developed sufficient reserves for regrowth which compromises yield and plant survival (Fulkerson and Slack 1995).

#### 2.1.2.6 *Breeding*

Pasture species in New Zealand have been subject to intensive breeding; consequently incremental increases in herbage yield have been achieved through the release of new cultivars. Woodfield (1999) estimated the gain in annual production from three major forage grasses (perennial ryegrass, tall fescue and annual ryegrass (*Lolium multiflorum* Lam.)) to be in the order of 0.25 – 1.18% per annum while Clark (2001) estimated that continued gains in breeding will increase production by 1% per year through the selection for increased stress tolerance of plants.

## 2.2 Pasture species

For brevity, only the species used in the experiments describes in this thesis are covered in this review.

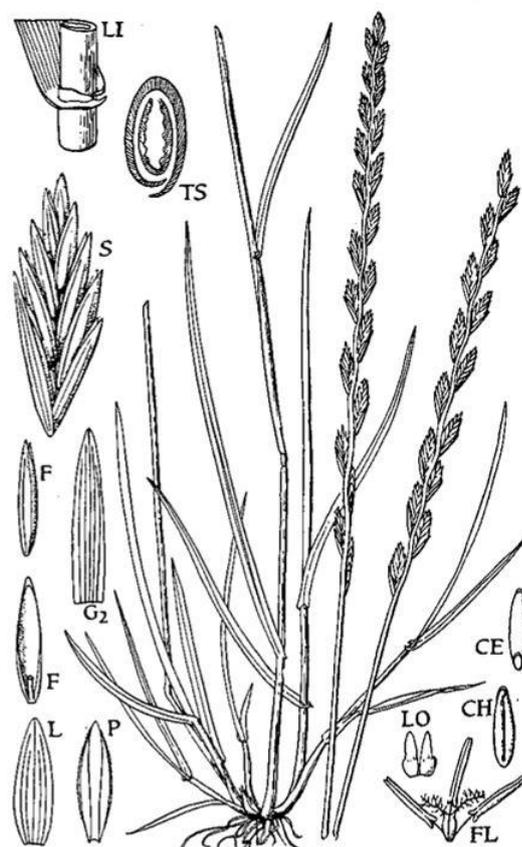
### 2.2.1 Perennial ryegrass

#### 2.2.1.1 *Morphology*

Perennial ryegrass is a densely tillering, cool season, perennial bunchgrass with an erect growth habit (Langer 1990; Thorogood 2003). Tillers are typically flattened, and bear hairless dark green leaves ( 2 – 6 mm wide, 3 – 20 cm long) that are ribbed on the upper surface and shiny on the lower (Lamp *et al.* 2001; Langer 1990). Young leaves emerge folded in the bud; but leaves developing on reproductive tillers may be rolled (Lamp *et al.* 2001) (Figure 2.5). The base of the sheath is red-tinged. The inflorescence of perennial ryegrass is a spike up to 20 cm in length. Perennial ryegrass can form stolons, which are prostrate stems that bear nodes from which independent plants can develop. The formation of stolons is cultivar specific and is normally induced under shading or hard grazing (Donaghy 2001).

Perennial ryegrass occurs naturally as a diploid, with a standard set of 14 chromosomes ( $2n = 2x = 14$ ) (Charlton and Stewart 2006). Plant breeders have doubled the chromosome number in some perennial ryegrass cultivars, using the ‘colchicine treatment’ technique as reported by Myers (1939) to form tetraploid types ( $2n = 4x = 28$ ) (Charlton and Stewart 2006; Nair 2004). Chromosome

doubling increases cell and vacuole size, increases water and soluble carbohydrate content and forms larger plants with larger seeds. The result of this, with respect to pasture, has been increased palatability, enhanced seedling vigour and a slight increase in digestibility (Charlton and Stewart 1999; van Bogaert 1975).



**Figure 2.5.** Morphology of Perennial ryegrass (*Lolium perenne* L.) (source: Lambrechtsen 1986). CE = grain showing embryo, CH = grain showing hilum, F = floret, FL = flower enlarged, G = glume, LI = ligule, LO = lodicules enlarged, P = palea, S = spikelet, TS = transverse section.

#### 2.2.1.2 Origin and adaptation

Perennial ryegrass is native to Europe, temperate Asia and North Africa. Perennial ryegrass is recognised for its value as a forage grass for livestock, and extensive research on this species has led to its wide distribution and use throughout the world including North and South America, South Africa, Australia and New Zealand (Lamp *et al.* 2001). This species is best adapted to cool moist climates receiving a minimum of between 457 – 635 mm rainfall per annum (Thorogood

2003). Perennial ryegrass performs best on fertile, well drained soils and will tolerate both acidic and alkaline soils (pH range 5.2 – 8.0) but superior production occurs when soil pH ranges from 5.5 – 7.5 (Anon. 2008; Hannaway *et al.* 1999).

#### 2.2.1.3 *Perennial ryegrass in New Zealand*

Perennial ryegrass was introduced into New Zealand around 1880 by English settlers who imported seeds from Europe (Charlton and Stewart 1999; Thom *et al.* 1998b). Distinct ecotypes have developed within New Zealand due to local environment and the farming practice for which they are used (Thom, 1998b). Thom (1998b) described two such ecotypes, including the Mangere ecotype that was developed under dairy cattle grazing that showed good tolerance to summer drought and superior winter production compared to other ecotypes. Until the late 1990's this ecotype was the main source of plant material for breeding of improved cultivars of perennial ryegrass (Thom *et al.* 1998b), but more recently material of Mediterranean origin has been used that show improved summer yield and have a later flowering date which delays the decline in forage quality associated with the onset of flowering (Woodfield and Easton 2004) so this does not coincide with peak lactation. In New Zealand, perennial ryegrass has become the most widely used temperate grass as it will grow in a wide range of soil fertilities and has proven to be easy to establish and manage with a satisfactory feed quality (Charlton and Stewart 2006).

#### 2.2.1.4 *Endophyte*

Naturally occurring populations of perennial ryegrass may contain a fungus that lives between the plants' cells, called an endophyte. The fungi and the grass host exist in a mutualistic symbiotic relationship (Charlton and Stewart 2006; Joost 1995), where the fungus derives its nourishment, as sugars, and means of reproduction from the grass and the grass host benefits from enhanced tolerance to biotic (i.e. pests, overgrazing) and abiotic (i.e. drought) stress (Joost 1995). Reproduction of the endophyte is asexual via the grass seed, where fungal hyphae are extended up the reproductive stem and into the grass ovule, effectively completing the endophytes life cycle within the host (Bacon and Hill 1996; Charlton and Stewart 2006; Tsai *et al.* 1994). Endophytes are host specific, with strains of the *Neotyphodium lolii* endophyte inhabiting perennial ryegrass. Endophytes produce chemicals called alkaloids and some have been identified as

deterrents to insect attack but are also causative agent for animal disorders. High levels of infection with the endophyte strain now termed ‘wild’ or ‘standard’, was a feature of early ryegrass cultivars (Easton 2007). At particular times of the year, livestock grazing these pastures suffered from the disorder known as ryegrass staggers. In 1981, Fletcher and Harvey identified the endophyte alkaloid lolitrem B as responsible for ryegrass staggers when the alkaloid is produced at high levels. Also, animal suffering from heat stress (thermoregulatory dysfunction) has been attributed to high concentrations of the alkaloid ergovaline (Fletcher *et al.* 1999). Both lolitrem B and ergovaline are produced by wild type endophyte. Endophyte-free perennial ryegrass was proposed but experimental work demonstrated that these pastures were susceptible to insect pests and did not persist (Prestidge *et al.* 1982; Siegel *et al.* 1985). However, the alkaloids peramine and ergovaline can be advantageous, giving ryegrass some resistance to the pasture pests Argentine stem weevil (*Listronotus bonariensis*) and adult black beetle (*Heteronychus arator*) (Popay *et al.* 2005; Popay and Wyatt 1995); this is further discussed in section 2.2.1.6. Therefore researchers have aimed to find strains of the endophyte that impart resistance to insect pests but do not produce the compounds harmful to animals (Latch 1994). New strains have been identified that fit these criteria, they are termed ‘novel’ endophytes and are included in the majority of ryegrass sold in New Zealand (Easton 2007). The perennial ryegrass type examined in the experimental work reported here contained the novel endophyte ‘Endo 5’. The Endo 5 endophyte produces peramine and low levels of ergovaline but not lolitrem B. Thus providing some protection from insects without, causing animal health problems.

#### 2.2.1.5 *Advantages of perennial ryegrass*

Perennial ryegrass pastures are able to withstand close frequent grazing and treading by stock (Charlton and Stewart 2006) making it suitable for use on intensive highly stocked dairy farm systems.

The seedling vigour of perennial ryegrass plants is superior to other temperate grass species. This enables a rapid establishment of pastures which is beneficial both for forage production and suppressing weed ingress into pastures (Kemp *et al.* 2000b).

Perennial ryegrass is valued as high quality forage. The pastures are palatable to stock and the forage is highly digestible providing high levels of energy, protein and minerals (Charlton and Stewart 2006; Kemp *et al.* 2000b).

#### 2.2.1.6 *Limitations of perennial ryegrass*

Perennial ryegrass performs poorly in hot conditions (Charlton and Stewart 2006). Mitchell (1956) determined that the optimal temperature range for ryegrass shoot growth is between 18-21°C, with substantial decline in growth above 29°C and the cessation of growth at 31°C (Thorogood 2003).

The root system of perennial ryegrass is relatively shallow, with the bulk of root mass located in the 0 – 20 cm region of the soil (Rollo *et al.* 1998). Consequently perennial ryegrass plants are sensitive to drought. Developed plants are capable of drawing water from up to 80 cm deep in to the soil profile compared to tall fescue that can extract water from depths greater than one metre (Garwood *et al.* 1979).

Endophyte-free perennial ryegrass is susceptible to pasture pests. Grass grub (*Costelyfra zelandica*), black beetle and Argentine stem weevil (ASW) are among the most damaging. The larvae eat the ryegrass roots, rendering the plant susceptible to drought and ‘pulling’ by livestock leading to reduced pasture production and survival (Popay and Baltus 2001). As mentioned in section 2.2.1.4 the novel endophyte infected perennial ryegrass contains certain alkaloids that deter (but not eliminate) insect feeding.

Crown rust (*Puccinia coronata*) is the most common fungal disease of perennial ryegrass. Infection occurs predominantly on older leaves in summer and autumn, and plants under drought or limited fertility are increasingly susceptible. Crown rust infection reduces herbage yield, quality and palatability (Clarke and Eagling 1994; Lancashire and Latch 1970).

The combined effect of these limitations is the reduced production of perennial ryegrass pastures particularly in summer with damage contributing to reduced persistence.

## 2.2.2 **Tall fescue**

*Lolium arundinaceum* (Schreb.) Darbysh. (syn. *Festuca arundinacea*) is the current name for tall fescue following a reclassification in the early 1990’s (Anon.

2008). However there is still debate regarding the nomenclature, as some regard the genera *Festuca* and *Lolium* to be taxonomically distinct though closely related (Anon. 2008); tall fescue is also widely referred to as *Festuca arundinacea* in the literature. Tall fescue is an allohexaploid, containing 42 chromosomes ( $2n = 6x = 42$ ) (Berg *et al.* 1979; Hopkins *et al.* 2009).

#### 2.2.2.1 Morphology

Tall fescue is a robust, cool season (Cowan 1956) perennial bunchgrass, with large tillers, and hairless large leaves (3 – 10 mm wide, 10 – 60 cm long) which are distinctly ribbed on the upper surface (Kemp *et al.* 2000b). Young leaves emerge rolled in the bud. The most distinguishable feature from perennial ryegrass is the inflorescence, which is a large, open panicle (10 – 20 cm long) with each spikelet containing 3 - 10 florets which separate at maturity (Lambrechtsen 1986) (Figure 2.6). Tall fescue has a dense fibrous root system (Lamp *et al.* 2001) capable of extracting water from over 100 cm into the soil (Garwood *et al.* 1979; Meyer and Watkins 2003b). Tall fescue is also able to develop rhizomes (an underground stem), which mostly occurs after the second autumn post sowing (Milne 2009) and can enhance persistence (Rollo *et al.* 1998).



**Figure 2.6.** Morphology of Tall fescue (*Lolium arundinaceum* Schreb.) (source: Lambrechtsen 1986). CE = grain showing embryo, CH = grain showing hilum, F = floret, FL = flower enlarged, G = glume, LI = ligule, LO = lodicules enlarged, P = palea, S = spikelet, TS = transverse section.

#### 2.2.2.2 Origin and adaptation

Tall fescue is native to Europe and North Africa (Hoveland 2009). Many ecotypes have evolved, adapted to a wide range of climates with natural populations found in arid to very wet sites (Easton *et al.* 1994). Tall fescue is also adapted to a range of elevation from sea level to 5000 feet (1524 m) (Cowan 1956). Within this tall fescue has adapted to most soil types including acid and alkaline (tall fescue can tolerate pH 4.7 – 8.5, however the optimal range is 5.5 – 6.5), medium to heavy textured soil or those subject to water-logging (Hannaway *et al.* 2009). Razmjoo *et al.* (1993) showed that tall fescue swards tolerated up to 8 weeks flooding in winter. However, the limits of its natural range are set by severe cold and rainfall below 450 mm per year (Easton *et al.* 1994).

Tall fescues adaptability means that it has become widely distributed throughout temperate regions of the world, including New Zealand where it has become successfully naturalised and is used as a forage species (Milne 2009).

#### 2.2.2.3 *Tall fescue in New Zealand*

Tall fescue was introduced into New Zealand from European sources in the 1880s (Anderson 1982; Brock 1983) where it was proposed for use in waterlogged wasteland areas. However the original cultivars were coarse, unpalatable to stock and cattle grazing tall fescue suffered from ‘fescue poisoning’ (section 2.2.2.7). As a result, tall fescue was disregarded for use as a pasture species and during the 1940s - 1950s most efforts were concerned with the eradication of the plant (Brock 1983) then termed an “undesirable weed” (Langer 1990). During this time however, tall fescue was gaining popularity in the United States of America due to its ability to provide green grass during extended dry periods in summer (Cowan 1956). In Europe in the 1960s and 1970s cultivars were developed that compared favourably with perennial ryegrass in terms of production and animal acceptance and did not cause fescue poisoning (Langer 1973). One such cultivar, ‘Abersywth S170’ was evaluated in New Zealand during this time and demonstrated favourable seasonal production (Watkin 1975), good survival during drought (Sheath *et al.* 1976) and a tolerance to grass grub (Kain *et al.* 1979) a significant pasture pest in New Zealand. Breeding a tall fescue cultivar specifically for New Zealand began in 1958 at DSIR Grasslands Division from a wide range of collections. Selection was for enhanced vigour, disease resistance and animal acceptance (Anderson 1982; Brock 1983). This culminated in the release of endophyte-free ‘Grasslands Roa’ in 1982 (Langer 1990). Before the release of ‘Grasslands Roa’, tall fescue use on farms was virtually nil (Anderson 1982). As the body of experimental data grew highlighting the benefits of tall fescue, and eliminating its reputation as a toxic species, the use of tall fescue increased (Brock 1983), with the introduction of tall fescue on to dairy farms occurring in the 1980’s (Martin and Moloney 1988). ‘Grasslands Roa’ was the most commonly used tall fescue until 1994 when it was replaced with newer cultivars that contained novel endophyte (MaxP™).

#### 2.2.2.4 *Endophyte*

As for perennial ryegrass, natural tall fescue populations can contain endophyte. Prior to 2003, all tall fescue seed sold in New Zealand did not contain endophyte. This was because of the toxic effect of the endophyte further discussed in section 2.2.2.6. The tall fescue cultivars evaluated in the body of the thesis contained the non toxic novel endophyte strain AR542 (also known as MaxP™ or MaxQ™) that produces peramine and lolines but not ergovaline.

#### 2.2.2.5 *Advantages of tall fescue*

Tall fescue has three main advantages over perennial ryegrass for use in dairy pastures in the Waikato: a superior tolerance to heat, moisture stress and pasture pests.

Tall fescue demonstrates a higher tolerance to heat than perennial ryegrass (Lowe and Bowdler 1995). Tall fescue is capable of maintaining growth up to ambient temperatures of 35°C compared with 31°C for perennial ryegrass (Anon. 2008).

Tall fescue has also been recognised as a species with moderate to good tolerance to moisture stress (Langer 1990). Garwood *et al.* (1979) demonstrated notably superior dry matter yield and survival of tall fescue plants compared to perennial ryegrass and cocksfoot under drought conditions. In New Zealand the use of tall fescue increased after droughts in the early 1980's highlighted the potential of this species to produce more feed that remained greener for longer than perennial ryegrass (Brock 1983; Charlton and Belgrave 1992). Several publications recommend the use of tall fescue as an alternative species in areas of New Zealand where the production and persistence of perennial ryegrass is limited by dry, hot conditions (Anderson 1982; Brock *et al.* 1982; Judd *et al.* 1990; McCallum *et al.* 1992). The enhanced tolerance to moisture stress of tall fescue can be attributed to the plants superior root system and its ability to make morphological and physiological adaptations to reduce water loss. Tall fescue is the deepest rooting cool season grass species (Meyer and Watkins 2003a), with the ability to extract moisture from below 100 cm in the soil profile compared to 80 cm for perennial ryegrass (Garwood *et al.* 1979). Furthermore, the number and weight of root material of tall fescue plants were greater at 50 – 100 cm soil depth than for other forage grasses such as timothy (*Phleum pratense*), cocksfoot

(*Dactylis glomerata*), Italian (*Lolium multiflorum*) and perennial ryegrasses in studies by Garwood *et al.* (1979) and Wilman *et al.* (1998); enabling greater extraction of soil moisture by tall fescue plants as demonstrated by Wilman *et al.* (1998). In response to moisture stress, tall fescue displays leaf rolling and stomatal closure to reduce transpiration (Renard and Francois 1985). Tall fescue is also capable of making osmotic adjustment in leaf blade tissues to avoid desiccation of cells (Assuero *et al.* 2000).

Tall fescue exhibits a greater degree of tolerance to the common pasture pests and pathogens that effect perennial ryegrass. In particular, once established tall fescue is tolerant of grass grub (Kain *et al.* 1979). Macfarlane (1990) suggested that the more robust root systems of tall fescue enables the plant to tolerate grass grub better than perennial ryegrass as similar grub densities were found in the soil from both pasture types. While McCallum *et al.* (1990) showed reduced grub numbers under pure tall fescue stands than under pure perennial ryegrass stands. Hence, several researchers have recommended tall fescue for use in grass grub prone areas in New Zealand (Judd *et al.* 1990; Milne *et al.* 1997). Endophyte-free tall fescue is less susceptible to ASW damage compared with ryegrass but is not immune to damage (McCallum *et al.* 1992; Popay *et al.* 2005; Prestidge *et al.* 1986). The endophyte strain AR542 (MaxP™) produces peramine and low levels of lolines. Hence MaxP™ provides good resistance to ASW and Black beetle (Charlton and Stewart 2006). In a feeding preference trial, Popay *et al.* (2005) showed that tall fescue infected with MaxP™ endophyte suffered no damage to tillers by adult black beetle compared with 58% of endophyte-free plants damaged; and a lower feeding score by ASW on endophyte infected plants compared to the endophyte-free plants of the same cultivar. Tall fescue has also demonstrated resistance to crown rust infection (Allo and Southon 1967; Lowe *et al.* 2008).

Herbage production, forage quality and dairy cow response to tall fescue in comparison to perennial ryegrass are discussed in section 2.3 of this review.

#### 2.2.2.6 *Limitations of tall fescue*

Soon after tall fescues introduction into New Zealand it gained a reputation for being toxic to livestock. In 1948, Cunningham published an article entitled “Tall

fescue grass is poison for cattle” in a popular scientific journal because animals grazing on tall fescue pasture for extended periods became lame. If the grazing continued the lameness would result in the loss of the hoof, a syndrome termed “fescue foot” (Cowan 1956). Also, animals grazing these pastures were more sensitive to heat stress with animals observed to seek shade or water and excessively drooling. Productivity losses through reduced feed intake and sub clinical effects have been documented (Schmidt and Osborn 1993). Thompson and Stuedemann (1993) also suggested that ergovaline in tall fescue may reduce serum prolactin, a compound important in the initiation of lactation. In 1977, Bacon *et al.* identified the endophytic fungus of tall fescue (*Neotyphodium coenophialum*) as the causative agent of fescue toxicoses. And shortly thereafter the endophyte was removed from commercial cultivars and “fungus-free fescue” was promoted (Easton 2007).

Early varieties of tall fescue were coarse and unpalatable to cows (Cowan 1956; Wright *et al.* 1985). Plant breeding has selected for traits, such as leaf tensile strength, to improve palatability (Callow *et al.* 2003) and there is some evidence that recent cultivars are more acceptable to stock (Milne *et al.* 1997). Although, in a grazing preference study by Horadagoda *et al.* (2009), tall fescue was the least preferred out of eight grass types. However, other researchers suggest that when tall fescue is properly managed it is highly palatable to cows (Cowan 1956; Milne *et al.* 1997; Praat *et al.* 1996), and Horadagoda *et al.* (2009) conceded that not all forages in the study were at their optimal stage for grazing.

Tall fescue can be difficult to establish, because it exhibits slow seedling vigour (Kemp *et al.* 2001) in comparison to other pasture species. Slow seedling growth allows the ingress of more vigorous weed species. The establishment phase is critical in determining future production and pasture persistence (Fraser and Lyons 1994), if tall fescue does not establish satisfactorily it will not usually “thicken up” in the pasture (Milne 2009).

#### 2.2.2.7 *Cultivars in New Zealand*

Two types of tall fescue are currently grown in New Zealand. Those termed ‘Continental’ (or ‘temperate’) type that originate from Europe or America; and a ‘Mediterranean’ type named so from the area from which these originated.

Continental tall fescue is the most commonly used type in New Zealand. These cultivars grow throughout the year, but are especially active during summer (Charlton and Stewart 2006; Milne 2001). Continental tall fescue is suited to regions that receive 600 – 700 mm or more rainfall per annum with reasonable seasonal spread (Milne 2001). Continental plants have an erect growth habit and tend to have fewer but larger tillers than Mediterranean plants (Assuero *et al.* 2000).

Continental tall fescue can further be divided into two types: soft or tough leaved. The soft leaved types have a later flowering date and provide high quality feed for dairy cattle, whereas the tough leaved types are more persistent in regions of low rainfall and high temperatures but are of lower feed quality (Anon. 2008; Milne 2001).

Mediterranean tall fescue is better suited than Continental types to regions that experience summer dry, but require reliable rainfall in winter of between 450 – 600 mm (Burnett 2006). Mediterranean tall fescue has been bred to extend pastoral areas into dry climates (Clark and Harris 2009). The growing season of Mediterranean tall fescue is from autumn through to late spring with varying degrees of dormancy during summer (Charlton and Stewart 2006; Milne 2001) ranging from complete dormancy to some summer production depending on the cultivar. Summer dormancy along with smaller plant size and a higher root:shoot ratio are an adaptation to moisture and heat stress and is part of the plants survival strategy (Anon. 2008).

A brief description of two cultivars evaluated for this thesis is outlined in the following:

‘Grasslands Advance’ tall fescue is a soft-leaved Continental type that was bred at DSIR Grasslands Division in the 1980s (Easton and Pennell 1993), and was first certified in 1990. Grasslands Advance is a synthetic<sup>2</sup> with 10 parents. The selection system involved assessment of grazed plots of maternal half-sibling families, with three cycles of selection beginning from pair crosses between plants related to Grasslands Roa and other sources, both imported and from New

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<sup>2</sup> Artificially bred.

Zealand collections (H. S. Easton *pers comm.* AgResearch). The main breeding objective in developing Grasslands Advance was to improve of the poor seedling vigour demonstrated by Grasslands Roa, enhancing seasonal growth whilst maintaining the palatability and forage quality of Grasslands Roa (Easton *et al.* 1994; Easton and Pennell 1993). Grasslands Advance is a late flowering cultivar (early November) with improved seedling vigour in comparison to Grasslands Roa (Milne 2001), high palatability to stock (Burnett 2006; Milne 2001), greater annual production (Fraser and Lyons 1994) and more even seasonal production than perennial ryegrass (Milne 2001; Nie *et al.* 2004), and excellent crown rust tolerance (Anon. 2008).

Resolute II tall fescue is a Mediterranean type developed by PGG Wrightson that originated from two cycles of recurrent selection from 'Resolute'. Resolute itself is derived from an Australian cultivar 'Melik' that was selected from seed collected at Wadi Melik, Israel. Selection for Resolute was for DM productivity, particularly in the cool season, grazing tolerance, disease resistance and uniformity; and for Resolute II there was also selection for endophyte density and transmission (M. Norris *pers comm.* PGG Wrightson). Milne (2001) described Resolute as having a semi-prostrate growth habit that exhibits varying degrees of summer dormancy as it will respond to moisture during this time.

### **2.2.3 Companion species**

The DM production and forage quality of temperate grasses fluctuates throughout the season, hence companion species with complementary growing seasons are routinely sown with these grasses to buffer feed deficit or add particular nutrients. Additionally monoculture pastures are most susceptible to abiotic and biotic stresses, so including companion species with differing climatic adaptation and better pest tolerance can mitigate stressors reducing production and prevent weed ingress (Lauriault *et al.* 2006). White clover (*Trifolium repens* L.) is the most common companion species and was described by Charlton and Stewart (2006) as New Zealand's most important forage plant. This is because white clover is of high nutritive value that increases milk yield when fed as a sole diet or with perennial ryegrass compared to yields from ryegrass alone (Harris *et al.* 1997; Johnson and Thomson 1996). White clover is also more drought tolerant than ryegrass (Karsten and MacAdam 2001), is tolerant of grazing and is capable of

fixing up to 380 kg N/ha/yr (Lowe and Fulkerson 2002) that is readily used by the companion grasses reducing the need for fertiliser N inputs. During the plants establishment it develops a tap root, but then exhibits clonal growth via stolon development and the tap root senesces. If the stolon is severed the plants remain alive and exist as an independent plant. Clover is not ideal as a sole diet as it can cause frothy bloat in ruminants. Red clover (*Trifolium pratense*) is less widely used but is also high quality forage. Red clover is a tap rooted species that enables the plant to provide superior yield in dry summers. However red clover is less persistent than white clover, lasting for 2 – 4 years in mixed pastures (Charlton and Stewart 1999). Chicory (*Cichorium intybus*) is again less widely used but has gained popularity recently for its superior drought tolerance which is due to its deep taproot (Charlton and Stewart 2006), and high level of production in spring and summer. Rollo *et al.* (Rollo *et al.* 1998) demonstrated that chicory out-yielded perennial ryegrass in summer by 1940 kg DM/ha. Chicory is also a high quality feed owing to high protein and mineral content in the plant (Lowe and Fulkerson 2002). The feed is also highly digestible, more so than ryegrass or white clover (Burke *et al.* 2000), meaning that animals are able to consume a large amount of chicory. However chicory is dormant over the winter months (Rollo *et al.* 1998) and contains secondary compounds called lactones that can provide benefit in terms of pest resistance to the plant but also flavour the milk (Charlton and Stewart 2006). Newer varieties have been bred for lower levels of lactones (Rumball *et al.* 2003).

### **2.3 Tall fescue as an alternative to perennial ryegrass**

Perennial ryegrass is likely to remain the dominant pasture species utilised in dairy pastures in the Waikato, for the reasons mentioned previously. However, the reliance of one pasture species to produce adequate forage year round, through extreme climate events is risky and imposes a limit on pasture production.

#### **2.3.1 Herbage production**

The herbage production from studies of ryegrass and tall fescue is variable. Table 2.1 summarises the annual DM production from tall fescue and ryegrass pastures from research conducted in New Zealand. While some studies have demonstrated

production advantages of between 5 and 20% from tall fescue pastures over ryegrass (Allo and Southon 1967; Goold and Hupkens van der Elst 1980; Judd *et al.* 1990; Thomson *et al.* 1988) others have shown that tall fescue produced 25% less annually when compared with ryegrass (Hainsworth *et al.* 1991). Variations in production from these studies may have been influenced by experimental design; a criticism of Thomson *et al.* (1988) and Judd *et al.*'s (1990) work is that they compare newly established fescue pastures with 30 year old ryegrass pastures. Pastures commonly exhibit decreases in yield over time (Neal *et al.* 2009) due to biotic and abiotic stresses and weed ingress, therefore comparing old with new pastures may not be without bias. Hainsworth *et al.* (1991) evaluated tall fescue stands that were established by direct drilling, a technique not recommended for tall fescue (McCallum *et al.* 1990) due to the weak competitive nature of fescue seedlings. However, other reports have shown that the annual DM production from tall fescue pastures are comparable to that from ryegrass pastures (Allen and Cullen 1975; Clark *et al.* 2010; Milne *et al.* 1997; Rollo *et al.* 1998; Watkin 1975). The overall differences in DM production results from studies are likely attributed to variations in climatic conditions during each of the experiments. As mentioned previously soil moisture and temperature in summer are major contributing factors in the production of pasture in New Zealand. A study by Rollo *et al.* (1998) in Hawke's Bay and Canterbury illustrates this. In the Hawke's Bay experiment average annual production of tall fescue and ryegrass based pastures over the four year study was similar. However, in the first two years tall fescue pastures yielded significantly more than ryegrass pastures, but in the following two years when the region experienced good summer rainfall and mild soil temperatures the ryegrass production was superior. Similarly in Canterbury, under varying levels of precipitation (dryland, moderate or full irrigation), tall fescue pastures were more productive under dryland and moderate irrigation than ryegrass (17 vs. 14.7 t DM/ha/yr); but under full irrigation, the ryegrass pastures showed a greater response, increasing production by 75% compared to dryland conditions, whereas the response from fescue pastures was 58% greater under full irrigation compared to dryland conditions. Work by Brock *et al.* (1982) supports these findings; in a grazing experiment, established tall fescue pastures produced 170% more than ryegrass pastures in a year when rainfall was only 55% of the normal levels, but in the second year of the

experiment when normal rainfall was experienced the ryegrass pastures produced more than the fescue. Annual DM yield is driven by the seasonal response of pastures. Relative to ryegrass, fescue tends to deliver a production advantage in the drier warmer months (Allo and Southon 1967; Judd *et al.* 1990; McCallum *et al.* 1992; Rollo *et al.* 1998). Clark *et al.* (2010) showed that tall fescue pastures produced 20% more DM than ryegrass in summer and Charlton and Stewart (2006) ranked the summer production of fescue a 3 and ryegrass a 1 on a 1-3 scale with 1 being poor and 3 good. However, again this response is largely influenced by climate. Advantages of up to 80% increased production of tall fescue over ryegrass were reported by Macfarlane (1990) in summer in Canterbury under irrigation. Macfarlane also noted that the increased production correlated with increasing soil temperatures. Clark *et al.*'s (2010) study in the Waikato showed that the irrigation response of fescue pastures was greater than perennial ryegrass (50% vs. 13% increase in DM from irrigated pastures compared to non-irrigated pastures). Yet, in a study by Parry *et al.* (1992), in Canterbury under mild summer temperatures, irrigated tall fescue pastures did not outperform irrigated ryegrass pastures; in those “no-stress” conditions the ryegrass pastures were more water use efficient than the fescue pastures (producing 22.3 vs. 21.9 kg DM/ha/mm water applied). Yields of tall fescue in winter are either comparable to (Exton *et al.* 1996; Kerrisk and Thomson 1990; Rollo *et al.* 1998) or below that of ryegrass (Clark *et al.* 2010; Hainsworth *et al.* 1991). These studies suggest that tall fescue and ryegrass have differing ranges of optimal temperature for production, and further to this tall fescue can exhibit a production advantage over ryegrass, but only when water or high temperatures are limiting ryegrass production.

The relatively slow establishment of tall fescue pastures is a main limitation to production in the first year and may negatively affect production in subsequent years. The slow establishment rate of tall fescue is due to a poor mobilisation of seed reserves and slow root growth. Relative to ryegrass, root appearance is later and root elongation is slower on tall fescue plants, which results in slower shoot growth and tillering rates (Brock *et al.* 1982). Germination of tall fescue seeds is also more sensitive to temperature. Charlton *et al.* (1986) measured germination rate of a various temperate grass species across a range of temperatures (5 – 30 °C) and found that the germination rate of ryegrass was greatest at all

temperatures. Germination of tall fescue was reduced at 5°C, where it took 23 days for 75% of the ryegrass seeds to germinate compared to 65 days for 75% germination of tall fescue seeds. Slow establishment results in reduced production. Yield measured 147 days after sowing was almost double from ryegrass than from tall fescue (974 vs. 595 kg DM/ha) in a study by Praat (1996). This trend was confirmed by Clark *et al.* (2010), who demonstrated 70% more yield from ryegrass than fescue from establishment to winter; and in a study in Queensland by Callow *et al.* (2003) the measured growth rate of fescue pastures was considerably less than ryegrass (< 10 vs. 21 kg/DM/ha/d). The slow growth of fescue seedlings means that they are poor competitors with weeds during establishment (Milne *et al.* 1997). Weed ingress results in reduced tillering (vegetative reproduction) and lowers the nutritive quality of the pasture. Therefore, establishment is a critical phase. Macfarlane *et al.* (1990) stated that tall fescue sowings tended to be either great successes or great failures. Milne *et al.* (1997) concurred suggesting that if establishment of tall fescue pastures is poor, then subsequent production will suffer as the pasture will not “thicken up” (i.e. produce enough tillers to form a dense sward). Special consideration to soil temperature at sowing and the complete eradication of resident plants is necessary when establishing tall fescue pastures.

Management of pastures affects DM yield (Section 2.1.2.5). Applying the same management guidelines to tall fescue pastures as for ryegrass pastures will compromise yield. Tall fescue pastures require more frequent grazing than ryegrass to match growth rate, optimise DM production and deter the formation of reproductive stems that reduce the quality of the pasture (Allen and Cullen 1975; Milne *et al.* 1997). Experiments in Taranaki (Kerrisk and Thomson 1990) showed that in a dry spring, tall fescue pastures were more productive under frequent defoliation (every 15 days) where growth rate was 35 kg DM/ha/day compared to 27 kg DM/ha/day under lax defoliation (every 30 days); whereas ryegrass produced more DM on a longer, 30 day rotation. Tall fescue is also more sensitive to severe grazing than perennial ryegrass. Kerrisk and Thomson’s (1990) study also evaluated the effect of different defoliation severities (lax, defoliating to a grazing residual of 4.5 – 5.5 cm; or hard grazing, residual 3 – 4 cm) on growth rate and showed that growth rate was reduced under hard grazing compared with

lax grazing. Further to this, a pot study (Kemp *et al.* 2001) that simulated continuous defoliation to a residual of 3 – 4 cm resulted in poorer DM production from tall fescue compared with ryegrass. The poorer regrowth was the result of slower leaf elongation and appearance (8.47 vs. 6.76 days/leaf/tiller for fescue and ryegrass, respectively), fewer tillers and the apparent response to the severe defoliation was that the fescue plant allocated more biomass to the roots than shoots compared with ryegrass (Kemp *et al.* 2001).

**Table 2.1.** Summary of dry matter yields (t DM/ha/yr) from research trials conducted in New Zealand. NB: parentheses denote resident pastures.

Author	Trial period	Ryegrass (non irrigated)	Tall fescue (non irrigated)	Ryegrass (irrigated)	Tall fescue (irrigated)	Defoliation	Stock	Tall fescue cultivar	Endophyte	Region
Allen & Cullen (1975)	1968-71	9	8.8			Cutting	-	S170	Nil	Southland - hill
		12.8	12.4			Cutting	-	S170	Nil	Southland - plain
Allo & Southon (1967)	1966-67	6.1	6.4			Cutting	-	S170	Nil	BOP
Clark <i>et al.</i> (2010)	2008-09	16.8	16.6			Grazing - rotational	Dairy	Advance	MaxP	Waikato
	2009-10	13.9	12.2	16.8	18.3	Grazing - rotational	Dairy	Advance	MaxP	Waikato
Hainsworth <i>et al.</i> (1991)	1987-90	(6.9)	6.4			Grazing - rotational	Dairy	Roa	Nil	Taranaki
Hay <i>et al.</i> (1997)	1992-96	10.7				Grazing	Sheep	Advance	Nil	Manawatu
Judd <i>et al.</i> (1989)	1982-88	(14.5)	17.5			Grazing - rotational	Dairy	Roa	Nil	Taranaki
Martin <i>et al.</i> (2008)	2006-07			12.9	15	Cutting	-	Advance	MaxP	Canterbury
McCallum & Thomson (1992)	1986-87	(6.3)	8.7			Grazing - rotational	Dairy	Roa	Nil	Taranaki
Rollo <i>et al.</i> (1998)	1990-95	(9.9)	10.4			Grazing	Sheep	AU Triumph	Nil	Hawkes Bay
	1982-88	(14.7)	17.0			Grazing	Dairy	Roa	Nil	Taranaki
	-	(8.0)	9.0	(14.0)	14.3			Roa	Nil	Canterbury
Thomson <i>et al.</i> (1988)	1983-86	(14.3)	16.9			Grazing - rotational	Dairy	Roa	Nil	Taranaki
Watkin (1975)	-	9.7	11.1			Grazing - rotational	Sheep	S170	Nil	Canterbury

### 2.3.2 Forage nutritive quality

Dairy cows are ruminants. They possess a rumen or 'fore-gut' where feed is partially digested by microorganisms. The dairy cow and the rumen microorganisms, which consist of bacteria, protozoa and fungi, exist in a symbiotic relationship. The microorganisms derive their nourishment and habitat from the dairy cow and the cow in turn receives nourishment from the products of microbial digestion (Waghorn *et al.* 2007).

The quality of a forage type can be defined in two ways, as either a nutritive (NV) or feed value (FV). The NV of the forage is determined by measuring the chemical composition of the forage and using this to estimate the energy content and digestibility of the feed. Then, surmising if these levels meet the metabolic demands and/or enable production (i.e. milk) of the grazing animal. There are three main indicators of NV of forages: metabolisable energy, crude protein content and fibre content and of the forage. The FV takes into account both the NV of the forage but also the amount of the forage the grazing animal can potentially consume, or 'intake'. Intake is influenced by the feeding drive or appetite of the animal, and rumen fill which is in turn limited by the availability of feed and the rate of digestion (Holmes *et al.* 2007; Waghorn *et al.* 2007). A positive relationship between intake and the digestibility of the feed consumed has been described. Where the more digestible a feed is the more the animal can consume (Holmes *et al.* 2007). Thus different forages and pastures have different FV. Feed value is a superior descriptor of forage quality but is more difficult to measure accurately (Waghorn *et al.* 2007).

The amount of energy forage contains is often the primary limitation to production (Waghorn *et al.* 2007). The metabolisable energy (ME) content of a forage is commonly used to compare forage types and is defined as the amount of energy available for maintenance and production (Charlton and Stewart 2006) and is expressed in units of mega-joules (MJ) per kg DM. For example, a cow in peak lactation will require about 208 MJ ME per day to maintain body condition (i.e. weight) and support lactation (Holmes *et al.* 2007). Therefore it is advantageous for the animal to select and the farmer to provide the highest quality feed possible, as lower quality feed will require a higher intake to meet the energy demands.

High quality forages are defined as those that contain above 12 MJ ME/kg DM. While low quality forages are those with less than 8 MJ ME/kg DM (Charlton and Stewart 2006). Reported ME values from tall fescue range from 11.3 – 12.0 MJ ME/kg DM and 10.9 – 11.8 for ryegrass (Burke *et al.* 2000; Milne *et al.* 1997). These values are similar and indicate these forages are of good quality for dairy cows.

Digested plant proteins yield amino acids. These are absorbed by the animal and used for the synthesis of new proteins for use by the cow for maintenance, growth, reproduction and lactation (NRC 2001). Crude protein content is the most common measure used in the literature to describe the protein content of forage. Kolver (2000) stated that to support lactation forages must contain at least 16 to 18% CP. In general, tall fescue and ryegrass pastures contain adequate protein, often in comparable levels. However, some reports have indicated higher levels of CP in tall fescue compared to ryegrass. In these instances, this was attributed to both a higher concentration of CP in the tall fescue plant compared to ryegrass (26 vs. 23%) (Burke *et al.* 2000; Milne *et al.* 1997) and also because tall fescue pastures tend to support higher clover content. On farm experience in the Waikato, reported by Milne *et al.* (1997) showed that white clover content in tall fescue pastures was 34%, whereas ryegrass pastures on the same farm comprised just 17% white clover.

The fibre content of forage can be determined by measuring the levels of neutral detergent fibre (NDF) in that feed. Neutral detergent fibre is the sum of the amount of non-readily digestible structural components of the plant cells (including cellulose, hemicelluloses and lignin) (NRC 2001). Therefore NDF can indicate FV, because fibre is tough, requiring a long time to break down in the rumen. This results in keeping the animal “full” which can lower intake (Waghorn *et al.* 2007) in turn potentially lowering production. However some fibre content in the forage is necessary to maintain rumen function (Holmes *et al.* 2007). This is because the presence of fibre stimulates chewing by the animal, which ruptures the plant cell walls releasing cell contents (Kolver 2000). Cell contents contain a large amount of protein and non-structural carbohydrates (i.e. sugars) that provide energy to the cow (NRC 2001). Chewing also stimulates saliva production which buffers the pH of the rumen, creating a suitable environment for microbial growth

(Kolver 2000). Kolver (2000) suggested that for forage to be termed 'good quality' it should contain a minimum of 35% NDF. Measured NDF content by Burke *et al.* (2000) of tall fescue and perennial ryegrass are above that required for rumination, at 49 and 42% of DM respectively. Milne *et al.* (1997) showed similar values at 42% NDF in tall fescue and 40% in ryegrass.

The nutritive quality of forage is not constant. The quality is influenced by physiology, season, plant maturity and management. Tetraploid varieties of perennial ryegrass have larger cell size than diploid varieties which results in higher cell and lower cell wall content, which enhances digestibility (Jensen *et al.* 2007). Young leafy pastures with tillers in the vegetative state also contain a greater proportion of cell contents than cell wall material. Because as pastures mature, cell walls strengthen to support the growing leaves, and in spring when highly fibrous reproductive stems develop, consequently the FV and digestibility of maturing pastures decline (Kemp *et al.* 2000b; Litherland and Lambert 2007; Valentine and Kemp 2007). Comparative studies between young leafy and mature perennial ryegrass show that protein and digestibility of pasture declines and fibre increases as pastures mature (Chaves *et al.* 2006; Waghorn and Barry 1987).

Tall fescue once had a reputation of being poorer quality than ryegrass (Fulkerson *et al.* 2000). This was because early cultivars of tall fescue were tough-leaved, containing a large amount of structural fibre (Milne 2001); but also management guidelines specific to tall fescue weren't well developed until the mid 1990's. Newer cultivars of tall fescue, such as Advance are less fibrous and consequently more palatable to cows, and management guidelines described by Milne *et al.* (1997) were developed. Well managed tall fescue and ryegrass pastures kept in a vegetative state, show similar levels of fibre and digestibility (Milne *et al.* 1997). The increase in fibre and decline in FV of digestibility of tall fescue also occurs more rapidly than observed in perennial ryegrass pastures (Callow *et al.* 2003; Lowe *et al.* 2009a). Therefore, the management of both pastures should be adjusted according to seasonal growth rate but particular care is needed to control stem and seed-head development in tall fescue pastures in spring (Charlton and Stewart 2006; Easton *et al.* 1994; Milne 2001).

### 2.3.3 Milk production

There are three main feed related factors that affect milk production: total annual DM production, the seasonal spread of the DM production and the nutritive value of the feed. Charlton and Stewart (2006) stated that annual and seasonal herbage yield is the primary factor that determines animal production, this is true in the respect that the amount of pasture produced sets the upper limit for animal production on pasture (Valentine and Kemp 2007). Using a simulation model to predict milk production, Barker *et al.* (1998) also determined that annual herbage yield is the most important factor affecting milk yield, with seasonal pasture growth having little effect. However other researchers dispute this, stating that increases in DM production will not always lead to increases in milk production (Callow *et al.* 2003). That increases will only occur if the additional feed is of high quality and is fed at a time when it meets the nutrient requirements of the cow (Hainsworth and Thomson 1997).

Studies comparing milk production from tall fescue with ryegrass based pastures have been contradictory. Similar milk yields (Wilson 1975) and milksolids (MS) yield (Thomson *et al.* 1988; Wilson 1975) have been reported from cows grazing tall fescue and perennial ryegrass pastures. However in two of the three studies reported by Wilson (1975), the fescue pastures contained considerably higher proportions of white clover than the ryegrass pastures (35 vs. 11% for the fescue and ryegrass pastures respectively). The higher clover content is likely to have enhanced milk yield as white clover has a high nutritive value that results in higher milk production when compared to forage grasses (Harris *et al.* 1997; Johnson and Thomson 1996). In Thomson and Barnes' (1990) study the animals were offered a generous feed allowance of 45 kg/ha/day. Maximum DM intake from pasture, by a high producing dairy cow is limited to 19 to 20 kg DM/cow/day (Kolver 2000) due to the rate at which this feed can be digested. The high herbage allowance would have allowed preferential selection of diet from the pastures. While clover content on both pastures was similar, at around 20% (Judd *et al.* 1990), the study did not determine the quality of the feed consumed; therefore the result is not conclusive. Other reports have suggested that while tall fescue pastures can increase pasture DM production this does not always lead to increases in milk production. From a farmlet study comparing milksolids

production from a tall fescue and phalaris (*Phalaris aquatica* L.) based pastures (60/40) to perennial ryegrass based pastures, Thomson *et al.* (1988) showed that annual production from the tall fescue was 18% greater than the ryegrass farmlet, but this did not result in an increase in MS production. Lowe *et al.*'s (1999) findings from an experiment in Queensland, Australia support this; where milk production from tall fescue was less efficient than from perennial ryegrass, that is: less milk was produced per unit of tall fescue DM offered.

However, management of pastures and the cultivar tested can affect the milk production response. Milne (1997) discounts the findings from Thomson *et al.* (1988), suggesting that the herbage mass (and maturity) of the fescue pastures offered was above that thought to provide optimal forage quality. Anecdotal evidence from commercial farms in the Waikato suggest that total milk yield and MS production from well managed fescue pastures is greater than from perennial ryegrass (Milne *et al.* 1997). Lowe *et al.* (2008) concur, stating that once management of fescue pastures is optimised milk production from ryegrass and fescue pastures is comparable.

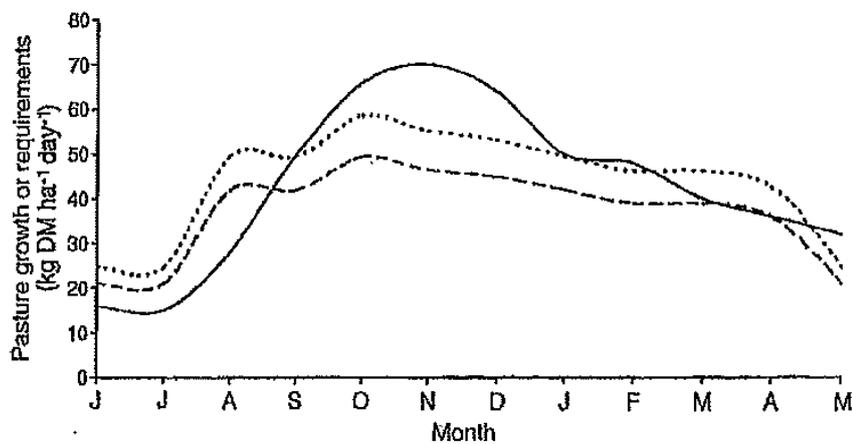
Also, more recent cultivars have been bred for enhanced palatability and digestibility (Section 2.2.2.7). The tall fescue cultivar AU Triumph is classified as a hard leaf type with a higher fibre content and lower digestibility than ryegrass, consequently in an experiment cows grazing AU Triumph pastures had the lowest milk yield of 10 fescue and 3 ryegrass cultivars tested under irrigation in Australia (Callow *et al.* 2003). Experiments using newer softer leaved cultivars such as Grasslands Advance demonstrate similar (Hainsworth and Thomson 1997) or enhanced milk production (+16%, Milne 2001) when compared with perennial ryegrass.

Advantages in MS production have been observed during dry conditions. In an evaluation of the effect of pasture mixes on MS yield, Thom *et al.* (1998a) showed that under normal climatic conditions, the MS production from tall fescue and existing perennial ryegrass pastures were similar in summer, but in the second year when a drought occurred, MS production from fescue pastures was greater than ryegrass pastures at 0.89 and 0.71 kg MS/cow/day respectively. This trend was also noted by Thomson *et al.* (1988) where MS production from fescue based

pastures was below that of ryegrass pastures in wetter years but was greater in dryer years, resulting in no significant difference over the four years of the trial. This may be partly due to the ability of fescue to maintain green leaf longer and therefore retain herbage quality longer under dry conditions than ryegrass (Kemp *et al.* 2004).

## 2.4 Implications for dairy pastures

As mentioned previously, while total production of pasture DM sets the upper limit for animal production from pasture, it is the seasonal distribution of this pasture and how well it meets the requirements of the animal that determines production how efficient the system is (Valentine and Kemp 2007). Clark *et al.* (1996) described the annual variation in perennial ryegrass based pasture supply as related to the feed requirements of intensive New Zealand dairy farms (Figure 2.7), and showed that in late summer and autumn feed demand often exceeds supply leading to a feed deficit.



**Figure 2.7.** Annual pasture growth curve (solid line) from the Waikato, New Zealand and pasture requirements for three (dashed line) and four (dotted line) cows per hectare. (Source: Clark *et al.* 1996).

Since tall fescue has been shown to be more heat and drought tolerant than ryegrass (refer to section 2.2.2.5) and more productive in warmer drier seasons (section 2.3.1), this species shows potential for filling the summer feed deficit when ryegrass pasture growth is reduced. Adequate feed supply during summer can reduce the rate decline of milk production from peak levels (Exton *et al.*

1996). Milne (1997) demonstrated this using the cultivar Grasslands Roa on a commercial dairy farm in the Waikato, where the rate of decline in production from Grasslands Advance tall fescue was 6.7% compared with 11% for perennial ryegrass pastures. Milne (1997) concluded that the seasonal spread of tall fescue growth better matched the needs of the lactating dairy cow.

Hainsworth and Thomson (1997) stated that additional feed will only increase milk production if it is of good quality. Tall fescue is a good quality feed (section 2.3.2), and as a pasture often contains more clover than ryegrass pastures do. Watkin (1975) found the white clover content in tall fescue pastures was 35%, a level that is nearer the optimal content for milk production (50%) as suggested by Harris *et al.* (1997) and above the 30% level required to have any significant effect on animal performance (Thomson 1984).

For these reasons, the evaluation of newer cultivars of tall fescue that contain novel endophyte warrant investigation for use in dairy farm systems in the Waikato.



### **3 PERFORMANCE OF AUTUMN AND SPRING-SOWN PERENNIAL RYEGRASS AND TALL FESCUE PASTURE MIXES UNDER DAIRY COW GRAZING AND IRRIGATION IN THE WAIKATO – PASTURE COMPOSITION AND TILLER DENSITIES.**

#### **3.1 Introduction**

Waikato dairy pastures are predominantly perennial ryegrass (*Lolium perenne*)-based as they are of high nutritive value, are easy to establish and highly productive. However, recent droughts and concerns regarding perennial ryegrass persistence have highlighted the limitations of this species in the Waikato. Previous research indicates that ryegrass persistence may be compromised by high temperatures ( $> 29^{\circ}\text{C}$ ) combined with low soil moisture (Meyer and Watkins 2003b; Mitchell 1956; Thorogood 2003). Insect feeding pressure, which often coincides with these limiting climatic conditions, may further reduce perennial ryegrass persistence (Popay and Baltus 2001). Compared with perennial ryegrass, tall fescue (*Lolium arundinaceum*) is more heat tolerant, maintaining growth up to  $35^{\circ}\text{C}$  (Anon. 2008) and exhibits superior survival under drought conditions (Garwood *et al.* 1979). Tall fescue has a higher degree of tolerance of grass grub (*Costelytra zelandica*), a common pasture pest in the Waikato, attributed to the more robust root system of the plant relative to ryegrass (MacFarlane 1990).

Several earlier studies using the tall fescue cultivar (cv) ‘Grasslands Roa’ concluded that this cultivar showed promise as an alternative species for use in regions where perennial ryegrass persistence is limited by dry, hot conditions and insect pressure, such as coastal Taranaki and the Bay of Plenty (Allo and Southon 1967; Brock 1983; Judd *et al.* 1990; McCallum *et al.* 1992; Milne *et al.* 1997). The warm temperate Waikato climate typically experiences only mild levels of drought stress (Charlton and Stewart 2006) and usually allows for good production from perennial ryegrass pastures. In a similar environment, inland Taranaki, it was determined that the endophyte free ‘Grasslands Roa’ tall fescue gave no superior advantage over perennial ryegrass (Hainsworth and Thomson 1997; Kerrisk and Thomson 1990) because of poor seedling vigour and slow

establishment. More recently, the Waikato region has recently faced several prolonged droughts, with the 2000 - 2009 being the warmest decade on record (NIWA 2010).

This raises concern about the reliance on a species, perennial ryegrass that is limited by hot, dry conditions. The more recently released tall fescue cultivars ('Grasslands Advance', a summer active Continental type; and 'Resolute II', a winter active Mediterranean type), have been bred for improved establishment (Easton and Pennell 1993; M. Norris *pers comm.*) and have also been infected with the novel endophyte MaxP™ (alternatively known as AR542 or MaxQ). MaxP™ is a strain of *Neotyphodium coenophialum* that broadens resistance to common pasture pests including Argentine stem weevil (ASW) (*Listronotus bonariensis*), black beetle (*Heteronychus arator*) larvae and adults, pasture mealy bug (*Balanococcus poae*) and root aphid (*Aploneura lentisci*). The availability of improved cultivars justifies re-investigation of tall fescue for Waikato dairy farms, as this species may mitigate the risk of feed deficits experienced with perennial ryegrass pastures in drought conditions.

The establishment phase of pastures is most critical as it largely influences future persistence and productivity; and tiller survival is an indication of establishment success. More persistent pastures with higher levels of companion species are advantageous to the dairy farmer for a number of reasons including, reduced need for pasture renovation that is costly (Glasse 2009) and has associated environmental ramifications (damage to soil structure, releasing soil carbon) (Davidson and Ackerman 1993). Secondly, through improved pasture quality. Watkin (1975) showed tall fescue is a better companion species for white clover from studies where tall fescue pastures contained up to 35% white clover, which is above the 30% level that Thomson (1984) suggested is required in order to have a positive effect on animal performance. Whereas, Caradus (1996) noted that typical perennial ryegrass-based pastures contain only 15 - 20% white clover. Thirdly, seasonal fluctuations in pasture supply can be buffered by the inclusion of a companion species with different seasonal growth patterns to the sown grass. Companion species may have morphological and physiological adaptations that enable them to better withstand certain climatic conditions than their associated species. The deep taproots of chicory (*Cichorium intybus*) and red clover

(*Trifolium pratense*), and the drought avoidance mechanisms (Hart 1987; Turner 1990) of white clover (*Trifolium repens*) can enable these species to withstand drought better than grasses. Consequently, the presence of companion species with a differing adaptive range and season of growth buffers the susceptibility of pastures to environmental stress, reduces weed encroachment and promotes a more uniform seasonal distribution of yield which is advantageous for feed budgeting (Lauriault *et al.* 2006).

We hypothesised firstly, that tall fescue-based pastures would have higher grass tiller survival than ryegrass-based pastures in the Waikato under dairy cow grazing in the establishing years; and secondly, that tall fescue pastures would support higher proportions of companion species when sown in mixture.

This chapter describes the changes in tiller density and botanical composition of irrigated and non irrigated tall fescue and ryegrass pastures sown at two different times under dairy cow grazing in the Waikato.

## **3.2 Materials and Methods**

A field plot trial was conducted to allow evaluation of the pasture species under practical conditions (i.e. on farm) enabling a large number of treatments (n=12) to be assessed with high replication (n=5) (t Mannetje 2000; Lynch 1966).

### **3.2.1 Site**

Field sowings were made in March 2007 (autumn sown, AS) and October 2008 (spring sown, SS) at DairyNZ's Scott farm near Hamilton (37°47'S, 175°19'E, 40 m a.s.l.). Six weeks before planting, existing perennial ryegrass-white clover pastures were sprayed with Roundup® Transorb (4 L/ha, glyphosate 540 g a.i./L) plus Pulse® surfactant (200 ml/100 L water). A fine, firm seedbed at the trial sites was prepared by ploughing and power harrowing to incorporate lime (2.5 t/ha autumn sown trial only) and Superten 7 K fertiliser (500 kg/ha; 7.7% P, 7.5% K, 8.9% S, 19% Ca) and rolling. Trial plots were sown using an Oyjord drill. An insecticide (Suscon Green: 15 kg/ha; a.i. 100g/kg chlorpyrifos) was applied at sowing to control grass grub, and urea was applied six weeks later (65 kg/ha; 46% N). Monthly rainfall and ambient temperatures were recorded at the Ruakura

Meteorological Station (37.8°S, 175.3° E). The soil type was a Matangi silt loam (Typic Orthic Gley) (Hewitt 1998). Soil analysis from samples collected before site cultivation showed Olsen P levels of 28 µl/ml and pH of 5.9 at the autumn sown experimental site; and Olsen P levels of 24 µl/ml and pH of 6.1 in the spring sown experimental site.

### 3.2.2 Treatments and design

Treatments were arranged in a 3 x 4 factorial combination of grass species and species mixes. The three grass species sown and sowing rates were: tetraploid perennial ryegrass (cv. 'Banquet II' with Endo 5; sown at 22 kg/ha) (PR), Continental tall fescue (cv. 'Grasslands Advance' with MaxP™; 32 kg /ha) (CTF) and Mediterranean tall fescue (cv. 'Resolute II' with MaxP™; 32 kg/ha) (MTF). The tall fescue cultivars were selected to compare the different seasonal growth patterns of Continental (summer active) and Mediterranean (winter active, summer dormant) types; and the tetraploid perennial ryegrass was selected for its high yielding capability aligning with the main objective of the research program to enhance pasture dry matter yield. The four species mixtures were: grass sown in a monoculture; grass in mixed sward with either red clover (cv. 'Colenso'; 4 kg/ha), white clover (cv. 'Kopu II'; 4 kg/ha) or chicory (*Cichorium intybus*) (cv. 'Choice'; 1.5 kg/ha). The companion species were selected for the compatibility of their seasonal growth patterns, suitability for dairy cow grazing and drought tolerance. Treatment plots (n = 60, each measuring 2.5 x 5 m) were arranged in two randomised complete block designs with five replicates (Appendix A).

### 3.2.3 Techniques

Irrigation was applied to one of the treatment blocks (I+) as determined by soil moisture content (SMC); the other block did not receive irrigation (I-). Soil moisture content was monitored weekly on both the I+ and I- blocks from October to May using a capacitance meter, taking 20 readings per block using 12 cm probes. When SMC fell below 35% (mid-point between field capacity and permanent wilting point of similar soil types, i.e. Te Kowhai silt loam, as determined by Singleton 1991) on the irrigated block, water was applied using sprinkler irrigators at a rate of 6 mm/hr until estimated field capacity was reached.

The experimental plots were grazed in rotation by dairy cows, with time of grazing based on visual estimate of herbage mass. Plots were grazed when estimated herbage mass (O'Donovan *et al.* 2002) on the highest yielding plot of ryegrass or tall fescue pastures reached 2800 kg DM/ha. Irrigated (I+) and non-irrigated (I-) blocks, and tall fescue and perennial ryegrass plots were grazed independently of one another. Fertiliser was applied after each grazing by replacing 4% of the measured dry matter (DM) yield as nitrogen using Yara Mila Complex fertiliser (12.4% N, 4% P, 15% K, 8% S, 1.7% Mg, 3% Ca).

Immediately before each grazing, from within each plot in replicates 1, 3 and 5, five hand-clipped herbage samples were taken, cut to retain 5 cm stubble, and bulked on a plot basis (as shown in Figure 3.1.). The herbage sample was thoroughly blended and botanical composition on a dry weight basis was determined by separating a sub-sample (approximately 40 g) into perennial ryegrass, tall fescue, chicory, white clover, red clover, weeds, other grasses and dead material of all species. Samples were dried in a forced-draught oven at 95°C for at least 24 hours before weighing to determine composition (Whalley and Hardy 2000). Seasonal botanical composition was calculated by averaging the botanical data collected from within the following periods: autumn – March 1 to May 31, winter – June 1 to August 31, spring – September 1 to November 30 and summer – December 1 to February 28/29.



**Figure 3.1.** Collection of samples for determination of botanical composition pre- grazing, May 2008.

Tiller density (tillers/m<sup>2</sup>) of tall fescue and ryegrass was determined during the establishment phase (6 weeks after emergence), and at the end of each season (as defined above). Four randomly placed 50 x 200 mm quadrats were placed within each plot and the number of grass tillers was recorded from each, from which tiller density was calculated as per Lynch (1966).

#### **3.2.4 Endophyte infection**

All seed used in these experiments was certified seed. Seed line information is presented in Appendix B. Endophyte infection was determined using the tissue print immunoassay technique (Hahn *et al.* 2003). Twenty vegetative tillers were collected at random from each treatment pre-grazing from both irrigated and non-irrigated experiments in autumn 2008 and 2009. Dead material was removed from each tiller and a clean scalpel was used to cut within 2 mm of the tiller base. The cut end was pressed firmly onto blotting paper with the coordinates of each blot recorded. Blotting paper was sent to AgResearch, Palmerston North for development using the immunoassay technique.

#### **3.2.5 Statistical analysis**

Data from both studies were analysed as a factorial design with a split plot layout using ANOVA (GenStat 12.1). Replicates and grazing area within each replicate were included as blocking factors in the analysis where each replicate had been

divided into two grazing areas, one for ryegrass and another for tall fescue. Pasture type was included as a treatment effect in the model. Analysis of transformed tiller and botanical data was assessed, with the results similar to untransformed data so for ease of interpretation, data presented here is untransformed.

### **3.3 Results**

#### **3.3.1 Climate**

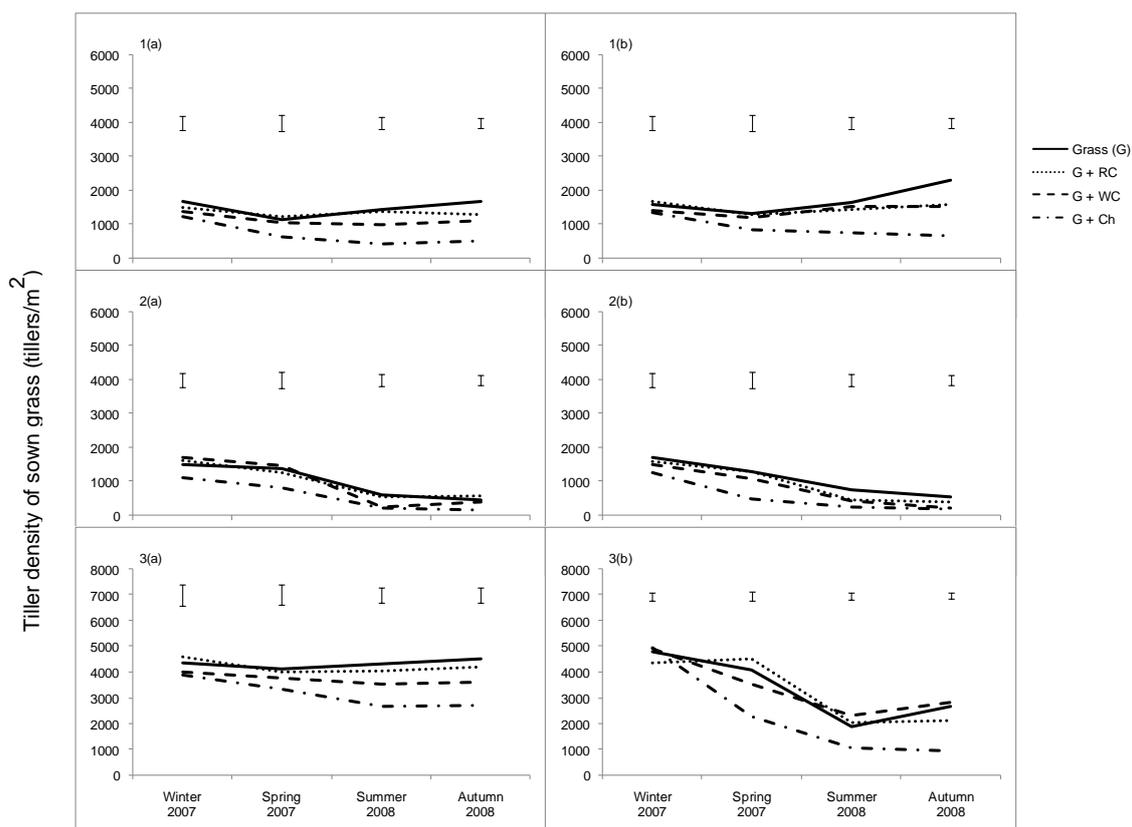
Monthly rainfall and average air temperatures recorded near the experimental site (Ruakura Climatological Station, 5 km from site) for the experimental period and 10 and 30 year averages are given in Table 3.1. Extremely low rainfall and above average temperatures during summer 2007/2008 resulted in a drought, when rainfall in January 2008 of 4.4 mm was the lowest on record (NIWA 2010). Low rainfall was also experienced in the autumns of 2009 and 2010 which was followed by a wetter than normal winter (2010). Winter 2009 was cooler than average.

**Table 3.1.** Monthly rainfall (mm), average air temperature (°C) and the 10 (1996 – 2005) and 30 year average (1975 - 2004) (source: AgResearch Ruakura Climatological Station).

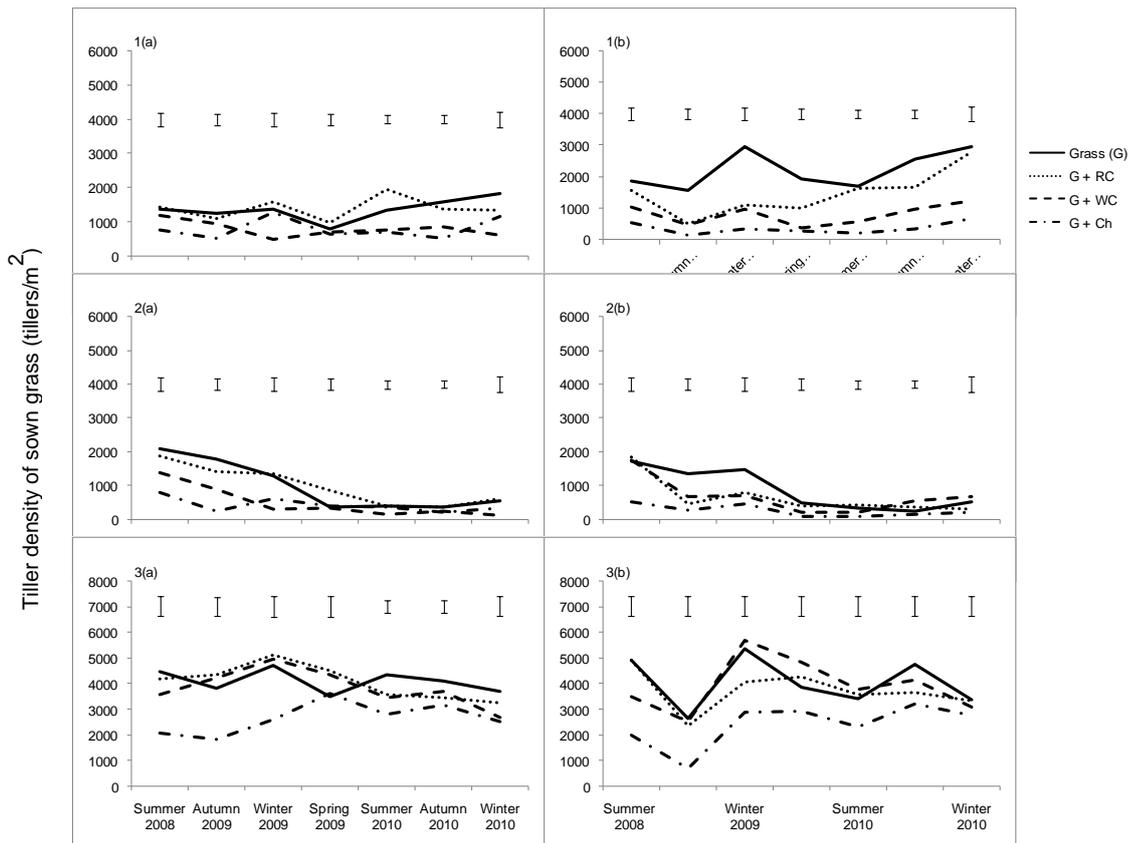
	Rainfall (mm)						Air temperature (°C)					
	2007	2008	2009	2010	10 yr av.	30 yr av.	2007	2008	2009	2010	10 yr av.	30 yr av.
Jan	.	4	45	154	61	85	.	20.3	18.1	18.2	18.4	12.9
Feb	.	26	152	24	86	75	.	19.0	19.3	19.9	19.0	13.6
Mar	99	36	32	15	79	83	18.2	18.0	16.2	16.6	17.3	11.2
Apr	59	113	72	31	72	90	14.0	15.2	14.3	14.8	14.7	8.9
May	22	84	102	109	106	97	12.9	10.4	9.6	11.8	12.7	7.0
Jun	104	161	122	232	108	117	9.7	9.8	7.1	9.5	10.2	4.7
Jul	158	212	128	56	122	125	10.2	9.0	8.0	8.2	9.2	4.1
Aug	113	173	103	158	89	106	10.4	9.8	10.9	10.2	9.5	5.6
Sep	61	70	119	150	98	93	11.9	11.4	11.2	12.9	11.7	7.0
Oct	92	160	134	31	86	92	12.8	13.2	11.9	13.8	13.5	8.7
Nov	51	37	41	22	91	94	14.3	14.9	13.9	16.3	14.7	9.9
Dec	73	144	96	.	113	98	17.6	16.9	16.1	.	16.9	11.8

### 3.3.2 Tiller density of sown grass

Average tiller densities of ryegrass and tall fescue were similar at both establishment phases, at 796, 683 and 641 tillers/m<sup>2</sup> for the PR, CTF and MTF treatments respectively, in the autumn 2007 sowing; and 879, 724 and 622 tillers/m<sup>2</sup> at the spring 2008 sowing. However, by the end of the season after sowing, ryegrass tiller density was markedly greater than tall fescue tiller density across all other seasons, irrigation regimes regardless of season of sowing (Figure 3.2. and Figure 3.3.). Tiller density was not significantly different (SED's 391.2, 336.5) between CTF and MTF in the first two seasons after sowing at both sowing dates, but by the third season (summer in the autumn sown experiment and winter in the spring established experiment) the average tiller density was significantly greater on the CTF treatments than on the MTF treatments.



**Figure 3.2.** Tiller density of sown grasses for (1) Continental tall fescue treatments, (2) Mediterranean tall fescue treatments and (3) tetraploid perennial ryegrass treatments, under (a) irrigated and (b) non-irrigated conditions from autumn sown pastures. Error bars represent SED.



**Figure 3.3.** Tiller density of sown grasses for (1) Continental tall fescue treatments, (2) Mediterranean tall fescue treatments and (3) tetraploid perennial ryegrass treatments, under (a) irrigated and (b) non-irrigated conditions from spring sown pastures. Error bars represent SED.

Figure 3.2. and Figure 3.3. describe changes over time in tiller density of pasture mixes from both I+ and I- blocks and sowing dates. The presence of companion species significantly affected tall fescue tiller density at all measurement times. In general, CTF tiller density was greater in either the monoculture pasture, or in mixture with red clover, but reduced in mixture with white clover and chicory. Tiller density of MTF pastures was lowest when sown with chicory ( $P < 0.001$ ) but similar between monoculture and in mixtures with clover in the AS experiment and in Year 2 of the SS experiment; but was variable in the Year 1 of the SS. Tiller density of CTF and MTF at all measurement dates showed similar seasonal trends (i.e. no species mixture interaction was observed), except for summer 2010 where the addition of white and red clover reduced MTF tiller numbers to a greater extent than observed on the CTF treatments. The presence of companion species did affect ryegrass tiller density in most seasons, excluding spring 2009 (SED = 784.0) and winter 2010 (SED = 768.2) where tiller density

was similar across all PR pasture mixes. Chicory had the largest effect on PR tiller density, which depressed tiller numbers by between 11 – 61% relative to monoculture pastures. However by the end of the two year SS trial there was no difference in ryegrass tiller density between mixtures (SED = 543.2).

Both MTF and CTF pastures showed a similar response to irrigation, i.e. there was no irrigation interaction observed between the two tall fescue types. However, the decline in tiller density during periods of high temperatures and low soil moisture on I-PR pastures was greater in magnitude than observed on the I-tall fescue pastures. In summer 2007/2008, I-PR tiller density decreased by an average of 1780 tillers/m<sup>2</sup> compared to 168 tillers/m<sup>2</sup> from I+PR pastures. Similarly in autumn 2009 a decline of 1780 tillers/m<sup>2</sup> vs. 10 tillers/m<sup>2</sup> for I-PR and I+PR respectively. These large declines in ryegrass tiller density coincide with drought events in the Waikato (Table 3.1.).

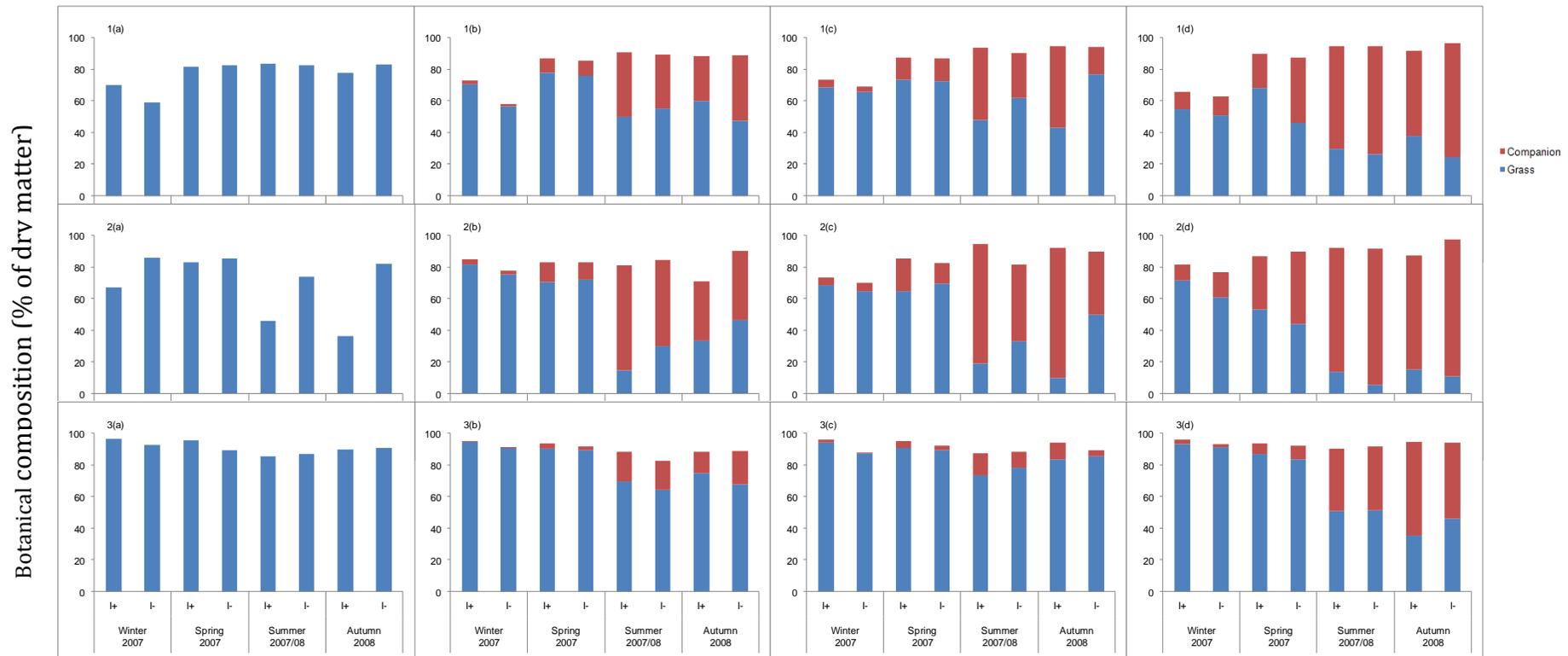
While it is not plausible to determine persistence of a species over a two year trial, important trends are noted. Initial CTF tiller growth was slow, but density of tillers increased from 1231 the season after sowing to 1587 tillers/m<sup>2</sup> at the end of the experiment; the greatest tiller density observed on the CTF pastures by the end of the experiment was I-CTF (1924 tillers/m<sup>2</sup>). MTF had the largest decline in tiller density over the experimental period, from 1499 tillers/m<sup>2</sup> in the season after sowing, to 422 tillers/m<sup>2</sup> at the end of the experiment; i.e. a reduction to 28% of the initial tiller density. Perennial ryegrass tiller density was variable, with the magnitude of fluctuation in tiller density considerably greater than observed on the fescue pastures during hot and dry weather conditions. For example, in autumn 2009 PR tiller density decreased by 2280 tillers/m<sup>2</sup> under I- conditions, equating to 45% loss in the tiller density observed in the previous season, compared with a 14 and 20% loss on I-CTF and I-MTF pastures respectively. At the end of the two year experiment a slight reduction in PR tiller numbers was observed (614 tillers/m<sup>2</sup>) on most pastures except PR+Ch where tiller density slightly increased.

### 3.3.3 Botanical composition

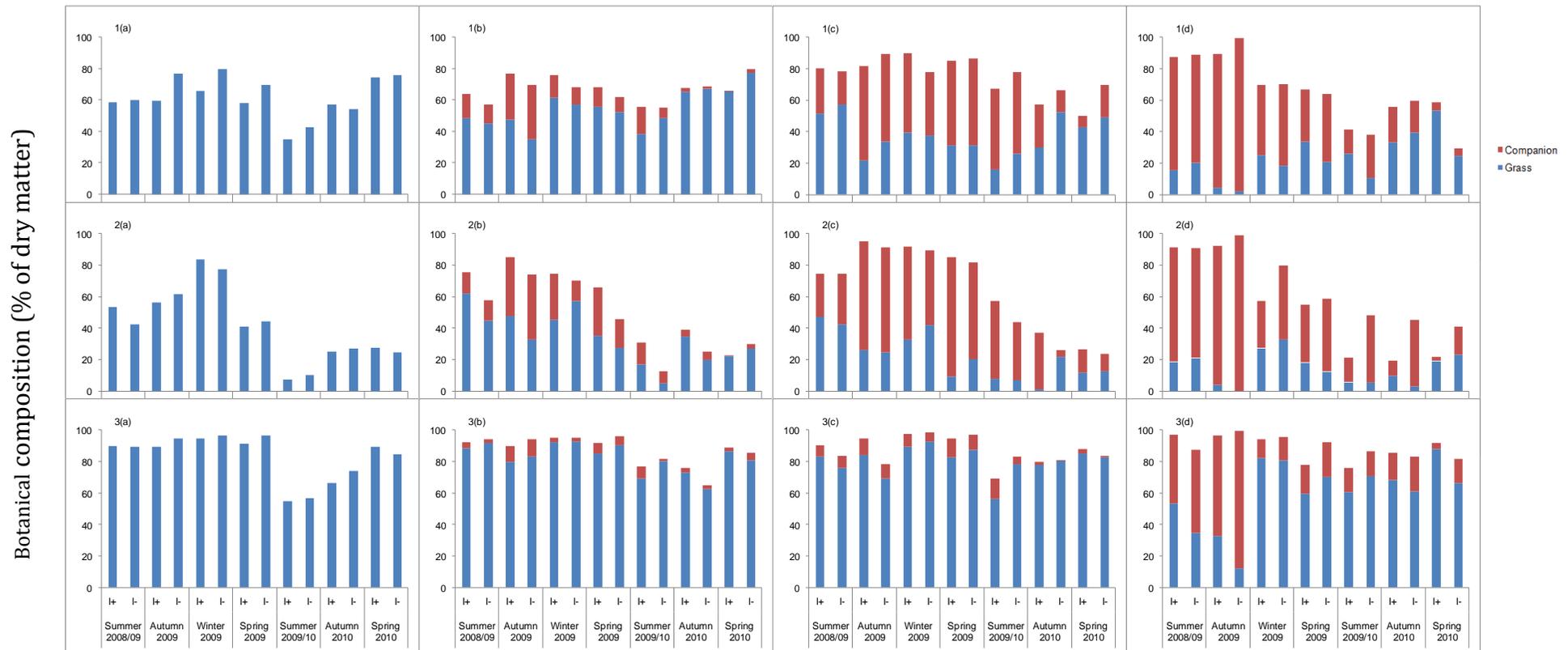
Proportion of sown grass (% of DM) in all pastures fluctuated throughout the seasons in each year and on both irrigation regimes (Figure 3.4. and Figure 3.5.). Average contribution of sown grass in the monocultures showed significant ( $P < 0.001$ ) differences between sown grass in most years, except in the first year of the SS experiment where there was no difference in tall fescue content between the CTF and MTF monoculture pastures (Table 3.2.).

Perennial ryegrass and CTF were the dominant species (>50%) in the monoculture pastures throughout the AS experiment under both I+ and I-; however, while MTF maintained a high proportion (>70%) for the duration of the AS non-irrigated experiment, an interaction was observed where MTF proportion was only 36% under I+ compared to 78 and 90% for the I+CTF and I+PR monocultures, respectively (SED = 7.1) by the end of the AS experiment. In the SS experiment, the amount of sown grass declined on all monocultures in summer of 2009/2010, coinciding with hot temperatures (Table 3.1.) and a large increase (av. 24%) in weed species (mainly summer annual grass weed species). By the end of the two year SS experiment, monocultures of CTF and PR remained sown grass-dominant at 75 and 87% of DM respectively, while the MTF pastures contained only 26% sown grass.

Overall, the addition of a companion species lowered sown grass proportion in all pastures (Table 3.2.). In the first year of both experiments a decreasing trend of sown grass across the tall fescue pasture mixtures was observed, with highest proportion on the monoculture > with red clover > with white clover > with chicory. In the second year of the SS experiment tall fescue with red clover pastures contained the highest proportion of sown grass followed by the monoculture > with white clover > with chicory. Perennial ryegrass component was greatest on the monoculture pastures followed by with white clover > with red clover > with chicory in the AS experiment and the second year of the SS experiment, but showed a similar trend as the fescue pastures in the first year of the SS experiment.



**Figure 3.4.** Average seasonal botanical composition in percentage of sown grass (blue bars) and companion species (red bars) in (1) monoculture pastures (2) grass plus red clover (3) grass plus white clover and (4) grass plus chicory under (a) irrigated and (b) non irrigated conditions from the autumn sown experiment.



**Figure 3.5.** Average seasonal botanical composition in percentage of sown grass (blue bars) and companion species (red bars) in (1) monoculture pastures (2) grass plus red clover (3) grass plus white clover and (4) grass plus chicory under (a) irrigated and (b) non irrigated conditions from the spring sown experiment.

**Table 3.2.** Annual average botanical composition (%) of monoculture and mixed pastures under irrigated and non-irrigated conditions in the one year autumn established trial and the two years on the spring established trial.

Treatment	Autumn sown (2007 - 2008)						Spring sown											
	Irrigated			Dryland			Year one (2008 - 2009)			Year two (2009 - 2010)								
	Sown grass	Companion species	Weeds	Sown grass	Companion species	Weeds	Sown grass	Companion species	Weeds	Sown grass	Companion species	Weeds	Sown grass	Companion species	Weeds			
<b>Effect of sown grass</b>																		
CTF	78	-	14	77	-	19	60	-	18	72	-	17	56	-	19	58	-	30
MTF	58	-	16	82	-	13	59	-	19	56	-	22	20	-	45	20	-	47
PR	92	-	7	91	-	10	91	-	6	94	-	5	90	-	26	85	-	23
SED	3.6	-	1.3	3.6	-	1.3	6.1	-	4.1	6.1	-	4.1	8.1	-	5.9	8.1	-	5.9
<b>Effect of addition</b>																		
CTF+RC	65	20	12	60	22	18	53	18	14	48	17	22	57	7	20	64	4	25
MTF+RC	50	30	12	56	28	14	47	28	13	41	21	20	25	6	41	17	5	51
PR+RC	82	9	7	68	10	9	86	6	5	89	6	4	87	4	17	81	3	20
SED	2.5	3.4	1.3	2.5	3.4	1.3	4.3	4.6	4.1	4.3	4.6	4.1	5.7	2.8	5.9	5.7	2.8	5.9
CTF+WC	58	29	12	69	16	14	36	48	13	40	43	12	30	29	37	43	29	24
MTF+WC	41	46	13	54	27	16	29	58	12	32	52	15	7	34	36	14	17	58
PR+WC	86	7.6	6	85	4.3	10	85	9	5	84	8	5	85	6	20	83	2	16
SED	2.5	2.6	1.3	2.5	2.6	1.3	4.3	7.0	4.1	4.3	7.0	4.1	5.7	8.4	5.9	5.7	8.4	5.9
CTF+Ch	48	38	12	37	49	14	20	59	13	15	66	15	38	14	19	25	18	36
MTF+Ch	39	49	10	31	59	10	17	57	14	17	66	14	12	9	37	10	34	41
PR+Ch	67	27	5	46	25	7	57	35	4	50	44	4	88	12	13	66	18	15
SED	2.5	5.0	1.3	2.5	5.0	1.3	4.3	10.9	4.1	4.3	10.9	4.1	5.7	6.2	5.9	5.7	6.2	5.9

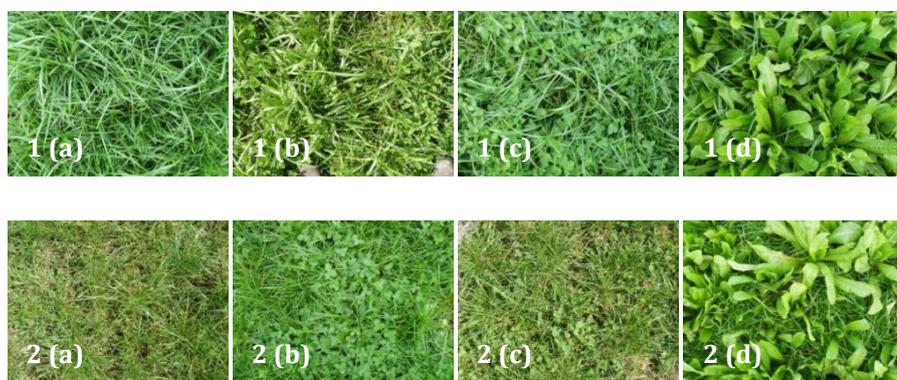
In all years tall fescue pastures maintained a higher proportion of white clover than ryegrass pastures (av. 36% v 6% for TF and PR respectively). Similarly, in all seasons except autumn and spring 2010, tall fescue pastures contained more red clover than ryegrass pastures. Generally, legume content on the MTF pastures was similar to the CTF pastures. In Year two of the SS experiment red clover content declined on all pastures corresponding with increasing sown grass. Legume content appeared greater in the PR pastures on the AS experiment than on the SS experiment. Dead material was consistently greater on the perennial ryegrass pastures ( $P = 0.012$  and  $< 0.001$ ), ranging from 1.4 – 6.0% between years, compared to 1.2 – 2.6 and 0.9 – 3.1% from CTF and MTF pastures respectively.

Chicory dominated (>50%) the tall fescue pastures in summer and autumn in the first year of both experiments and the ryegrass pastures in autumn 2009. Between the non-irrigated and irrigated experiments chicory dominance over ryegrass was inconsistent, with greater chicory under non-irrigated conditions in summer 2009, but greater under irrigation in autumn 2008. Chicory content was significantly greater on the tall fescue pastures than on the ryegrass pastures in all seasons in the first year in both experiments, comprising 54, 43 and 26% (SED = 5.0), and 61, 62 and 39% (SED = 7.7) of MTF, CTF and PR pastures in the AS and SS trials respectively, peaking at 98.8% on the MTF+Ch pasture in autumn 2009 under non-irrigated conditions. Chicory proportion declined in the second year of the SS experiment and was similar between sown grasses (range 9 – 14%, SED = 6.2).

In all seasons the amount of weed species was significantly greater on the tall fescues pastures (range 13 – 44%) than the ryegrass pastures (range 5 – 19%), except for autumn 2008 where there was a greater proportion of weed species on the ryegrass pastures under non-irrigated conditions. Proportion of weeds was similar between tall fescue pastures in the first year of both experiments but in the second year of the SS experiment the proportion of weeds was greater on the MTF pastures than the CTF pastures (44 vs. 26%, SED = 2.1).

There were observed differences in the pasture composition between irrigation regimes. In the AS experiment tall fescue content in mixtures with chicory was

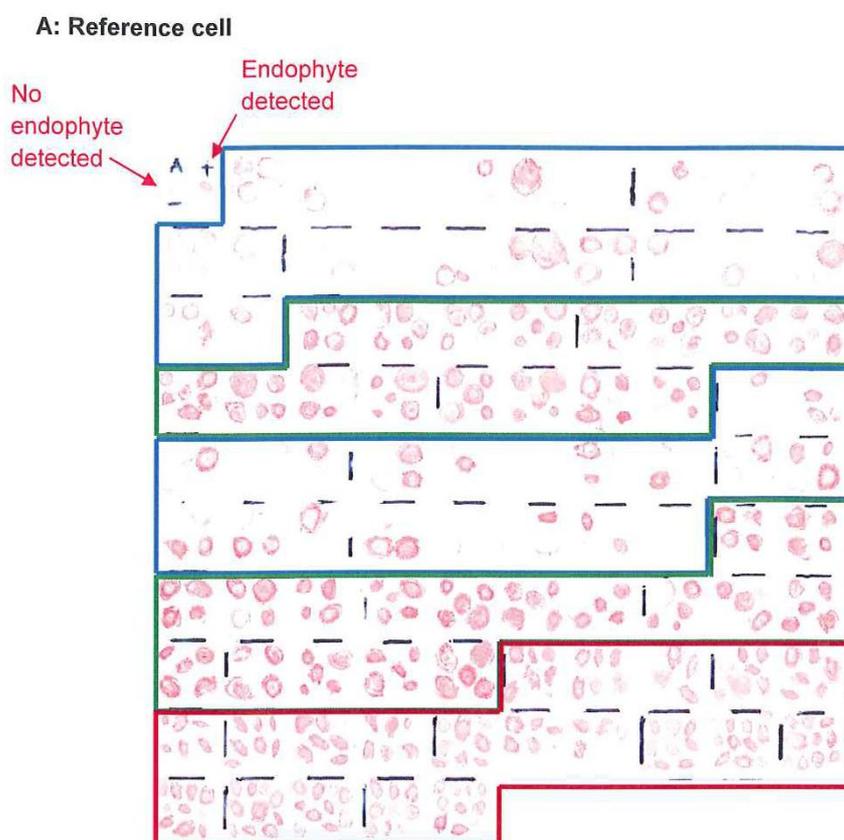
reduced under I+ in spring 2007 ( $P < 0.01$ ) but decreased in autumn 2008 ( $P < 0.001$ ). In summer 2007/2008 tall fescue pastures supported more white clover under I+ than I- (46 vs. 28%). Irrigated pastures of PR+Ch had similar proportions of each sown species in autumn 2008, however under I- conditions chicory dominated the pastures. In the SS experiment the amount of weeds in the tall fescue pastures was greater under I- conditions compared to I+, whereas the proportion of weeds was similar between I+ and I- PR pastures. In autumn 2010 PR and MTF was reduced in pastures containing chicory without irrigation, and in spring 2010 CTF and MTF was also reduced when sown with chicory under non-irrigated conditions. Examples of the pastures are shown in Figure 3.6.



**Figure 3.6.** Example of pastures from (1) Continental tall fescue and (2) perennial ryegrass, in (a) monoculture (b) mixed with red clover (c) with white clover and (d) with chicory, May 2008.

### 3.3.4 Endophyte infection

Percent endophyte infection at the end of Year 1 of the AS experiment was 35, 94 and 94% for CTF, MTF and PR, respectively, and 52, 93 and 96% for CTF, MTF and PR, respectively from the SS experiment. An example of the results from the AS experiment is shown in Figure 3.7. Pale blots denote no endophyte presence, whereas the darker pink blots indicate endophyte presence. Clearly the endophyte infection was much lower on the CTF pastures than the MTF and PR pastures at this time.



**Figure 3.7.** Developed tiller blot from tillers collected in autumn 2008. Blots from Continental tall fescue (outlined in blue), Mediterranean tall fescue (green outline) and Perennial ryegrass (red outline) tillers are shown. Dark pink blots denote endophyte presence, faint blots indicate endophyte absence.

### 3.4 Discussion

These results indicate that perennial ryegrass tiller density declined during prolonged periods of hot dry conditions, because declines in tiller density coincided with periods of extremely low rainfall and high temperatures (summer 2008 and autumn 2009). This is in line with previous research that has demonstrated ryegrass tiller decline in similar conditions (Lowe *et al.* 2008; Nie *et al.* 2004; Thom *et al.* 1998a). However tall fescue tillers exhibited superior survival compared to perennial ryegrass during hot dry conditions as the magnitude of ryegrass tiller density loss was 7.5 times greater than observed on the fescue pastures. Thom *et al.* (1998a) observed a similar decline in ryegrass tiller density coinciding with periods of low rainfall in the Waikato, as did Nie *et al.* (2004) in Victoria, Australia and Lowe *et al.* (2008) in Queensland, Australia (respectively). Where Nie *et al.* (2004) recorded losses of tillers from ryegrass based pastures to be up to 2.5 times greater than the loss observed on alternative grasses (including tall fescue). The enhanced survival of tall fescue relative to perennial ryegrass is presumably partly due to its physiological and morphological adaptations including a very fibrous deep root system (Meyer and Watkins 2003a). However different species exhibit different stress survival strategies. Following the steep decline in PR tiller density, a rapid increase in tiller numbers was observed, to a level similar to pre-drought density. This indicates an ability of the ryegrass plant to recover after drought, where the plant can exhibit avoidance mechanisms to survive drought by reducing photosynthetic tissue to reduce water loss by transpiration (Volaire 1998), with tiller replacement likely arising from growth of previously dormant axillary buds at the base of dead tillers (Kemp and Culvenor 1994; Silsbury 1964) when the soil moisture and heat stress abated.

A measure of persistence suggested by Nie *et al.* (2004) is for the pasture to maintain a botanical composition with over 70% sown species. In order to achieve this Nie *et al.* (2004) suggested that species density should be maintained at over 3000 growing points (i.e. tillers) per m<sup>2</sup> for ryegrass-based pastures and > 2300 growing points/m<sup>2</sup> for alternative grasses such as tall fescue. Continental tall fescue monoculture pastures showed a trend of increasing tiller density and contribution to the pasture over the duration of the experiments, which supports

previous work (Allen and Cullen 1975; Hainsworth *et al.* 1991). However CTF tiller density only surpassed the suggested threshold in the autumn of 2008 (autumn trial) and autumn and winter 2010 (spring trial) under non-irrigated conditions. Though, these experiments demonstrated that monoculture tall fescue pastures maintained > 70% tall fescue content from tiller densities as low as 1200 tillers/m<sup>2</sup>, suggesting that Nie's *et al.* (2004) figure be re-evaluated for this cultivar in New Zealand. The tiller density of MTF pastures declined over time, never exceeding 2300 tillers/m<sup>2</sup> irrespective of season of sowing or irrigation regime. Declining MTF tiller density resulted in a low contribution of MTF to the pasture by the end of each experiment, indicating that MTF is unlikely to persist satisfactorily on a Waikato dairy farm. Despite considerable fluctuation, PR tiller density in pastures remained relatively consistent between the beginning and end of most experiments except under I- conditions on the AS experiment where a large decline in tiller density was observed. Hernández Garay *et al.* (1997), similarly observed fluctuations in perennial ryegrass pastures, concluding that the pastures are dynamic entities where tiller density changes in accordance to management and season, and therefore tiller survival is best determined by the net change in tiller density. Using tiller survival and pasture composition to infer pasture persistence, these data suggest that MTF is less persistent than either CTF or PR in the Waikato under dairy cow grazing. While CTF remained the dominant species present in the pastures at the end of the SS experiment and that the proportion of CTF and PR in the pastures was similar indicates that persistence of CTF is similar to that of PR. This agrees with the findings of Hainsworth and Thomson (1997) from studies in south Taranaki but is contrary to our original hypothesis that tall fescue would exhibit superior tiller survival than PR. Further long term research is necessary to fully determine the persistence of each species, and investigation into the cause of the decline in endophyte in CTF, and to what extent this reduces persistence.

While advances in plant breeding have improved the establishment of tall fescue varieties (Easton and Pennell 1993), the results of this experiment confirm that tall fescue is slower to establish than ryegrass as shown by the lower rate of increase in tiller density between sowing and the following season of both experiments. As trends in grass tiller density increase after sowing was similar, this suggests the

establishment vigour is driven more by plant physiology than climatic factors. Kemp *et al.* (2001) using an earlier cultivar (Grasslands Roa) demonstrated that the slower establishment of tall fescue is a function of the plant, resulting from a slower tiller appearance rate than PR even under non-limiting laboratory conditions. Slow establishment of tall fescue allows for greater weed (predominantly broad leaf weeds and annual grasses such as *Poa annua*, *Digitaria sanguinalis* and *Panicum dichotomiflorum*) ingress into these pastures compared with the PR pastures (Table 3.2.). Nie *et al.* (2004) reported a similar phenomenon with a significant negative exponential relationship ( $R^2 = 0.63$ ,  $P < 0.01$ ) between the density of sown grass and volunteer species. Others (e.g. Allen 1975) also report more weed ingress in tall fescue than PR pastures suggesting PR has a superior competitive ability against broadleaf and grass weeds compared to tall fescue (Praat *et al.* 1996).

While the slower establishment of tall fescue enables weed ingress, it does enable tall fescue as a suitable companion for other forage species. Tall fescue pastures supported higher companion species content than ryegrass pastures. White clover is a common companion species in dairy pastures as the forage can have a positive effect on milk production when it comprises between 30 – 55% of the pasture (Harris 1997; Harris *et al.* 1998; Thomson 1984). A white clover content of greater than 55% was only achieved on the tall fescue pastures in some seasons; overall the white clover content was on average six times greater on the tall fescue pastures than the PR pastures, and closer to the 30% level suggested by Thomson (1984). This suggests that tall fescue and white clover mixed pastures have a higher milk production potential than perennial ryegrass; this was shown by Wilson (1975) who acknowledged that the enhanced milk production from cows grazing tall fescue-based pastures relative to perennial ryegrass-based pastures may have also been due to the increased white clover content in the tall fescue pastures. Similarly tall fescue pastures supported higher contents of red clover than did the ryegrass pastures, indicating that tall fescue is a suitable companion species for both legumes. Although legume component did decline in the second year with increasing sown grass content, or in the case of MTF with increasing weed ingress.

The use of chicory has increased in recent years due to its high level of production in spring through to autumn and tolerance to drought conditions (Charlton and Stewart 2006). However, the vigorous nature of the chicory as observed in these experiments, where it dominated the tall fescue pastures in the summer and autumn in Year 1 of both experiments, indicate that chicory was not a suitable companion species for tall fescue and would likely compromise long term pasture persistence. This conclusion is supported by Hume *et al.* (1995) who demonstrated sown grass yields were strongly inversely related to content of chicory ( $R^2 = 0.82$ ,  $P < 0.001$ ). Perennial ryegrass appeared to have a greater capacity to compete with chicory, as PR+Ch pastures did exhibit a reduction in tiller density, chicory had a shorter season of pasture dominance when sown with ryegrass compared with tall fescue.

Season of sowing appeared to influence pasture composition, although this was could not be statistically analysed. Changes in sown grass and companion species component in the sward reflects the differing growing seasons of each species (Figure 3.4. and Figure 3.5.). Grass dominance was observed in the cooler seasons, with increasing companion species content in the warmer months. In the SS experiment, warm temperatures at establishment promoted early chicory and white clover dominance thus reduced tall fescue tiller density and proportion in the pastures, which remained low for the duration of the experiment in accordance with Milne *et al.*'s (1997) statement that if the establishment of tall fescue is poor then it is unlikely to "thicken up" in the pasture. These results indicate that when sowing tall fescue with clover that an autumn sowing is recommended, to allow for the slower establishing tall fescue to increase tiller density before conditions become favourable for optimised clover growth. Similarly, an autumn sowing date is recommended for mixed pastures of PR, but in this case to allow better establishment of companion species by minimising competition from PR, and to avoid the risk of pasture failure from drought (Thom *et al.* 1985). These results also show that successful establishment of spring sown CTF and PR monoculture pastures is achievable.

The application of irrigation influenced both the sown grass tiller density and seasonal species composition of the pastures. The reduction in sown grass contribution to the pasture over time was lessened by irrigation, as measured in

the two year SS experiment. Sown grass contribution was reduced by 14 and 9% on I-CTF and I-PR pastures respectively, compared to 4 and 1% from I+CTF and I+PR pastures. The reduction in CTF content observed in these experiments is substantially lower than the 30 – 40 % decline reported by McCallum *et al.* (1992) in Taranaki. However, the work by McCallum *et al.* was conducted using endophyte-free ‘Grasslands Roa’ tall fescue, which would have been more susceptible to pasture pests (Popay and Baltus 2001) , than the MaxP infected tall fescue in this experiment. As mentioned previously, periods of hot dry weather resulted in considerable plant loss from the ryegrass pastures, as was also reported by Thom *et al.* (1998b). Seasonal fluctuations in tiller density were moderated under irrigation compared with non-irrigated conditions, particularly in the SS experiment. Grass tiller loss was 3.5 times greater during periods of drought on I-pastures than from I+ pastures, suggesting that soil moisture is a major determinant of grass survival, more so than temperature.

In terms of pasture composition, under I- conditions the better adapted, deeper rooting tall fescue and chicory plants dominated the other sown species, and allowed the chicory to better compete with perennial ryegrass that was limited by hot dry conditions. While irrigation promoted the growth of the legumes in summer in the tall fescue pastures it did not improve overall legume content as also observed by Thom (2001).

### **3.5 Conclusion**

Despite the slow establishment of CTF the content of tall fescue increased over the course of the experiment, showing similar contribution to the pasture as perennial ryegrass at the end of the two year trial.

While tall fescue tiller survival was superior to that of perennial ryegrass during hot and dry climatic conditions, ryegrass tiller density returned to similar levels observed pre-drought suggesting that ryegrass tiller death during drought is a survival mechanism of the plant.

Irrigation appeared to reduce sown grass population decline during hot and dry conditions periods and over time.

These results confirm previous research that tall fescue pastures support higher legume contents than perennial ryegrass pastures. This is beneficial in terms of increasing the nutritive quality in dairy pastures.

Chicory, sown at 1.5 kg seed/ha with tall fescue would likely reduce the long term persistence of tall fescue pastures under dairy cow grazing in the Waikato.

### **3.6 Further research**

To ascertain the persistence of tall fescue in dairy pastures in the Waikato, a longer term trial is necessary. A larger scale farmlet type experiment evaluating the milk production response of the higher legume containing fescue pastures would be valuable. In terms of sowing chicory in mixture with tall fescue to enhance summer dry matter production, over-sowing it into established tall fescue stands may also be worthy of investigation.

## **4 PERFORMANCE OF AUTUMN AND SPRING-SOWN PERENNIAL RYEGRASS AND TALL FESCUE PASTURE MIXES UNDER DAIRY COW GRAZING AND IRRIGATION IN THE WAIKATO – PASTURE DRY MATTER PRODUCTION AND NUTRITIVE VALUE.**

### **4.1 Introduction**

In New Zealand, grazed forage provides most of the feed on dairy farms. Where approximately 70% of farms rely largely on grazed pastures to feed cows, importing just 4 - 20% of feed (usually in the form of energy dense concentrates, i.e. maize silage) to either supplement dry cows or to extend lactation (DairyNZ 2010a; b; c; Headley *et al.* 2006). Thus the annual amount of pasture grown, the seasonal distribution of the amount of pasture grown throughout the year and the nutritive value of that pasture, directly influences farm milk production (Holmes *et al.* 2007) and profitability.

The production and nutritive value of each species in a pasture is determined by its genotype, and how it responds to external factors including abiotic stressors (i.e. climate, including rainfall, temperature and light), biotic stressors (weeds and pests) and management practices (i.e. grazing management, fertiliser inputs etc.) (Chapter 2). Consequently, the optimal conditions for maximising growth are different for each pasture species. McMeekan (1964) stated that climate is the main determinant of actual pasture growth, and Rawnsley *et al.* (2007) considered temperature and rainfall the most important. Thus, the annual cycle of changing climatic conditions results in a seasonal variation in pasture feed supply (Valentine and Kemp 2007). This variation in supply is one of the main limitations of a pasture based dairy system (Clark *et al.* 1996). Efficient utilisation of pasture occurs when pasture supply matches the feed requirement of the dairy herd (Holmes *et al.* 2007; Valentine and Kemp 2007) or if low winter growth is compensated by a growth surplus in the spring, from which silage can be conserved and used during those periods of low growth. Therefore, unpredictable climatic events (i.e. drought) or extremes can result in an unanticipated period of low pasture growth that can potentially cause a feed deficit on farm.

In the Waikato, dairy pastures are predominantly mixtures of perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*), and their seasonal growth patterns are well understood. Maximum pasture growth occurs in the spring (c. 80 kg dry matter (DM)/ha/day) and minimum in winter (c. 20 kg DM/ha/day) (Baars *et al.* 1991; Holmes *et al.* 2007). Mitchell (1963) estimated the potential annual yield from pastures in the Waikato to be 24 t DM/ha based on average temperature and radiation levels, however, the actual average is between 12 – 17 t DM/ha (Holmes *et al.* 2007). The gap between potential and actual yield means that increases in forage production can be made if key constraints are removed. Possible means of achieving this include, the use of alternative species to perennial ryegrass, incorporating companion species with complementary growth patterns, and/or utilising irrigation when soil moisture is limiting.

Tall fescue (*Lolium arundinaceum*) has potential as an alternative pasture species to perennial ryegrass as it is a widely adapted species that will grow on a wide range of soil types (Meyer and Watkins 2003b) and those subject to water logging (Gibson and Newman 2001) as occurs in the Waikato on the peat-based soils. Compared to perennial ryegrass, tall fescue has a wider range of temperature tolerance, being both more cold and heat tolerant, (Anon. 2008). In the Waikato low growth rates in perennial ryegrass pastures result from both low winter (< 4°C, Thorogood 2003) and high (> 21°C, Mitchell 1956) summer temperatures, potentially leading to a feed deficit. The use of an alternative pasture species with a wider range of temperature tolerance may mitigate the issues associated with reduced feed supply during these times. Adding to this, recent droughts in the Waikato have highlighted the poor performance of perennial ryegrass during periods of low soil moisture. Plants with deep root systems are better adapted to tolerate low soil moisture. Tall fescue plants have an extensive and deep fibrous root system, that enables water extraction from below 1 m in the soil profile (Meyer and Watkins 2003b). Ryegrass however, draws water from approximately 80 cm deep (Garwood *et al.* 1979) but maintains most of its roots (80%) within the top 7 cm of soil (Houlbrooke 1996) making the plant susceptible to low soil moisture. Thus ability to draw water from depth combined with a number of tall fescue's physiological adaptations (leaf rolling, stomatal closure and osmotic adjustment, (Assuero *et al.* 2000; Renard and Francois 1985; Wright *et al.* 1985)

make tall fescue potentially more resistant to moisture stress than perennial ryegrass. Much of the published research conducted in New Zealand has used tall fescue cultivars of a continental origin (CTF, also known as 'Temperate' cultivars). These varieties can exhibit growth throughout the year, but mainly from spring to autumn. Droughts in the early 1980s highlighted the superior drought tolerance of continental tall fescue as these pastures were observed to produce more DM and remain greener for longer than did those based on perennial ryegrass (PR) (Brock 1983; Charlton and Belgrave 1992). Previous research has also shown that continental tall fescue has the potential to produce higher annual DM yields than ryegrass (Judd *et al.* 1990; McCallum *et al.* 1992; Thomson *et al.* 1988), mainly because of superior DM production in the warmer months (Allo and Southon 1967; Clark *et al.* 2010; Judd *et al.* 1990; McCallum *et al.* 1992; Rollo *et al.* 1998). Tall fescue of Mediterranean origin is also available in New Zealand. 'Mediterranean tall fescue' (MTF) has a growing season from autumn to spring, and may exhibit some dormancy in summer. There is little published research on MTF use in New Zealand, yet the winter activity of these cultivars may be beneficial in providing feed when other grass species are limited due to low temperatures. Summer dormancy of MTF cultivars may also promote survival during periods of water stress in the Waikato.

The addition of companion species with differing growing seasons to forage grasses can buffer fluctuations in seasonal forage supply. While the primary growing season for temperate forage grasses is from autumn through to spring, legumes, such as red and white clover are most productive in summer (Holmes *et al.* 2007). Additionally, tap-rooted species such as chicory or red clover that have the capacity to draw water from deep within the soil profile can provide additional feed in times of low soil moisture (Valentine and Kemp 2007) when production from temperate companion grasses can be limited.

The nutritive value (NV) of forage grasses also varies throughout the season. The addition of a companion species into a pasture can potentially compensate for times when the NV of pasture grasses is low (i.e. summer). The NV of forage grasses is largely influenced by the change from leafy vegetative growth in winter to the development of reproductive growth consisting of lignified stems and seed-heads which occurs in late spring. The maturity of the forage (i.e. grazing

rotation), temperature and the amount of dead material in the pasture (Litherland and Lambert 2007) also influence NV. Therefore, in general the NV of forage grasses is highest in winter and early spring and lowest in the summer when mature seed-heads are present in the sward, air temperatures are high causing cell wall digestibility to be reduced (Litherland and Lambert 2007), and lower rainfall reducing the decomposition of dead material. In general, legumes and chicory are less affected by age and temperature and do not accumulate dead material to the same extent as grasses. These species have a high NV as they contain high levels of metabolisable energy (ME) and crude protein (CP), contain low levels of fibre (Burke *et al.* 2000; Valentine and Kemp 2007) and are thus highly digestible, more so than forage grasses. Higher digestibility of forage is advantageous as it has been shown to increase feed intake by livestock, the main driver of animal production (Waghorn *et al.* 2007). The less vigorous growth of establishing tall fescue plants, relative to ryegrass means that it is a more suitable companion species for legumes (Watkin 1975) and chicory, as described in Chapter 3.

New Zealand receives ample radiant energy to achieve high DM yields (Clark *et al.* 2001), but low soil moisture content can be a limitation (Thom 2000). Typically from November to March evapotranspiration exceeds rainfall in the Waikato, leading to a deficit in soil moisture (Clark *et al.* 2010). Irrigation is one means of mitigating low soil moisture. However, while the area of irrigated land has continued to increase throughout New Zealand (to 31% of total New Zealand dairy pastures, Anon 2009; a rate of increase of 55% each decade, Lincoln Environmental 2000), water is a limited resource and future demands may exceed supply. Therefore, species such as tall fescue, that have been shown to be more water use efficient than perennial ryegrass (Clark *et al.* 2010; Martin *et al.* 2008) and warrant investigation in the Waikato.

Despite the potential of tall fescue to improve DM production, its use has been limited due to slow establishment, reputed low palatability and lack of persistence. The latter, in earlier cultivars, was in part due to improper management and the lack of an endophytic fungus to deter pest attack (Brock 1983; Milne *et al.* 1997). The recent development of cultivars bred for enhanced establishment, DM production and palatability (Easton and Pennell 1993; Fraser and Lyons 1994) with the inclusion of a non-toxic novel endophyte, MaxP™,

which protects against a wide range of pasture pests, has renewed interest in this species. These improved cultivars also warrant evaluation for use in dairy pastures in the Waikato as they could buffer the gaps in feed supply resulting from poor perennial ryegrass production during climatic conditions outside the range for optimal perennial ryegrass growth.

It is hypothesised that annual dry matter yields of tall fescue with Max P™ endophyte will be greater than for endophyte-infected perennial ryegrass when grazed by dairy cows in the Waikato. The objective of this study was to compare the effect of sown grass species, and species mixture on seasonal and annual pasture production and the nutritive value of these pastures established on two different sowing dates, under both irrigated (I+) and non-irrigated (I-) conditions and dairy cow grazing.

## **4.2 Materials and Methods**

Site, experimental treatments and design, and fertiliser regime are detailed in Chapter 3.

### **4.2.1 Techniques**

Management of pastures was based on guidelines outlined by Milne *et al.* (1997) and Kerrisk and Thomson (1990). The experimental plots (2.5 x 5 m) were rotationally grazed by dairy cows. Pasture mass was determined by weekly visual estimates of total herbage mass, from which growth rate was then estimated and grazing frequency determined. When estimated herbage mass on the highest yielding ryegrass or tall fescue plot reached 2800 kg DM/ha, the pastures were grazed. Irrigated and non-irrigated blocks of tall fescue and perennial ryegrass-based pastures were grazed independently of one another (Figure 4.1.). Therefore, the number of grazing events differed between sown grass treatments and between irrigated and non-irrigated experiments. The number of cows and grazing time was also determined by pre-grazing pasture mass and that was to be grazed to residual herbage heights of 5 cm for tall fescue and 4 cm for ryegrass. Typically, between 30 and 35 cows grazed the plots for between 2 - 4 hours. Pasture DM yield was assessed before each grazing using the strip technique (Lynch 1966) where a 2.5 m<sup>2</sup> strip was cut within each plot using a rotary mower set to retain a

5 cm stubble height (Figure 4.2.), the recommended defoliation height for tall fescue (Milne 2009). The fresh weight (to the nearest 50 g) of the cut herbage from each plot was recorded in the field using a hanging scale (Salter, Victoria, Australia) suspended from a tripod. From the weighed cut herbage, a representative subsample was taken for determination of DM content. The fresh weight of the subsample (to 1 decimal place) was recorded in the laboratory, and then dried in a forced-air oven at 95°C for 36 h before re-weighing. Within 24 hours of the harvest, the experimental plots were grazed as outlined above. Herbage yield of each plot was calculated by multiplying the weight of the cut herbage by the DM content of the subsample. Seasonal pasture DM yield was calculated by summing the data collected from within the following periods: autumn – March 1 to May 31, winter – June 1 to August 31, spring – September 1 to November 30 and summer – December 1 to February 28/29. Total annual yield was then calculated by summing the DM yield from all cuts taken over 12 months from the sowing date of each experiment.



**Figure 4.1.** Experimental plots, showing grazed tall fescue pastures and un-grazed perennial ryegrass pastures in the foreground, November 2007.



**Figure 4.2.** Mowing of experimental plots for determination of pasture yield, using a rotary mower.

On the same date as each harvest, hand-clipped samples were taken from random locations within each plot in replicates one, three and five. Each sample was cut to a 5 cm stubble, and bulked per treatment. After blending the bulk sample, a 150 g subsample was taken for estimation of nutritive value. The subsamples were dried in a forced-draught oven at 60°C for at least 24 hours before grinding in a mill to pass through a 1 mm diameter sieve. Dried and ground samples were sent to feedTECH®, AgResearch for estimation of forage nutritive value by determining the levels of various indicators (levels of: ADF, acid detergent fibre; NDF, neutral detergent fibre; CP, crude protein; Ash, OMD, organic matter digestibility; ME, metabolisable energy; SSS, soluble sugars and starch and lipids) of feed quality using near infrared spectroscopy (NIRS; Corson *et al.*, 1999).

#### **4.2.2 Statistical analysis**

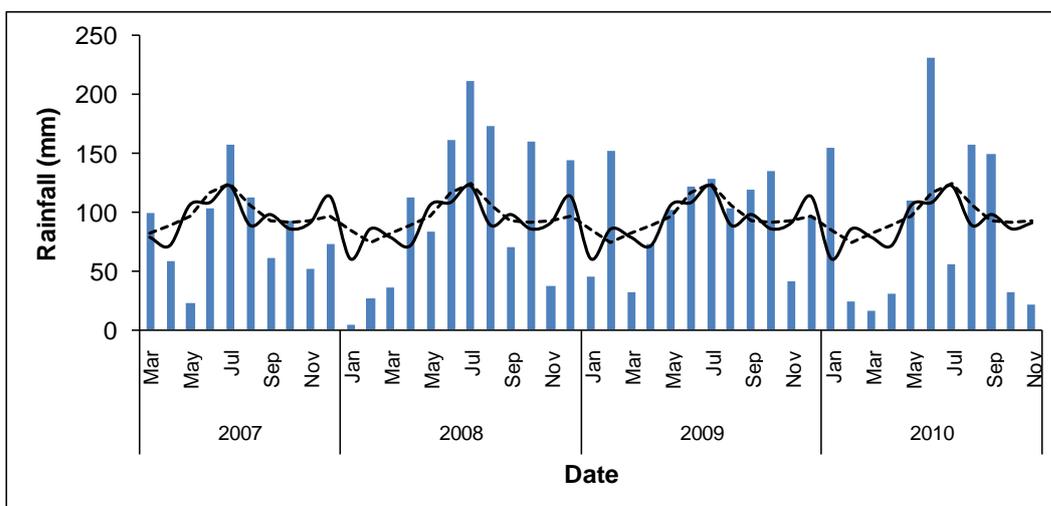
Data from both studies were analysed as a factorial design with a split plot layout using Analysis of Variance (GenStat 12.1). Replicates and grazing area within each replicate were included as blocking factors in the analysis where each replicate had been divided into two grazing areas, one for ryegrass and another for tall fescue. Pasture type was included as a treatment effect in the model.

The effect of irrigation could not be directly compared statistically in this experiment as the irrigated and non-irrigated experimental blocks were separated by distance to ensure that the soil moisture content in the non-irrigated experimental area was not influenced by the irrigation occurring on the irrigated block. However irrigation interactions were able to be determined.

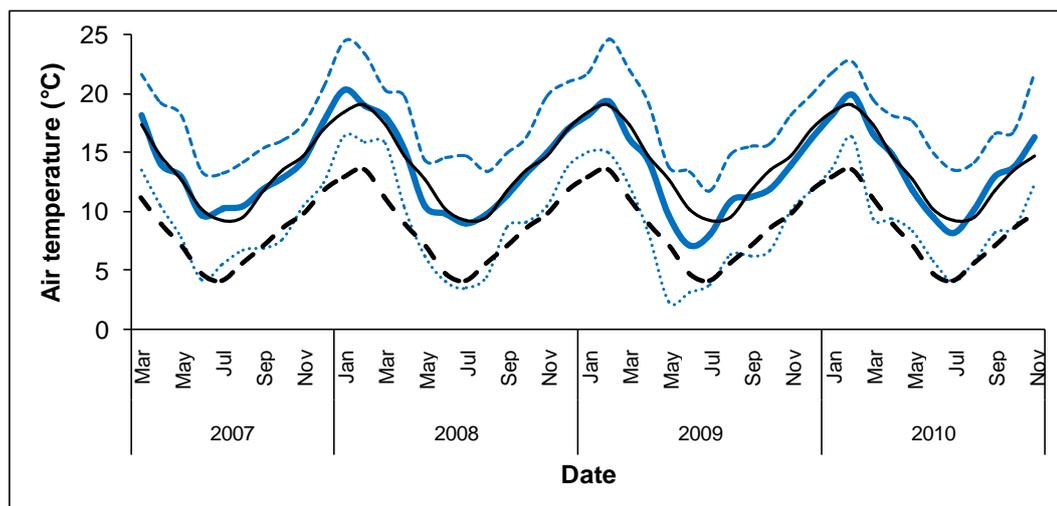
## 4.3 Results

### 4.3.1 Climate

Total monthly rainfall and the average daily mean, minimum and maximum air temperature ( $^{\circ}\text{C}$ ) recorded at the Ruakura Climatological Station from March 2007 to November 2010 compared with the 10 and 30 year monthly averages (Figure 4.3. and Figure 4.4.). The 2007-2008 summer and 2010 autumn were considerably drier, and the 2008 winter wetter than the 10 year average. Mean air temperature was similar to the 10 year average (except for a cooler winter in 2009) but was considerably warmer than the 30 year average.



**Figure 4.3.** Total monthly rainfall (blue bars) during the experimental period (March 2007 - November 2010); the 10 year, 1996 - 2005 (solid black line) and 30 year, 1975 - 2004 (dashed black line) average monthly rainfall recorded at the Ruakura Climatological Station.



**Figure 4.4.** Average daily mean (solid blue line), mean daily minimum (dotted blue line) and mean daily maximum (dashed blue line) temperatures ( $^{\circ}\text{C}$ ) during the experimental period (March 2007 - November 2010); and the 10 year, 1996 - 2005 (solid black line) and 30 year, 1975 - 2004 (dashed black line) average daily temperature ( $^{\circ}\text{C}$ ) recorded at the Ruakura Climatological Station.

#### 4.4 Annual DM yield

Total harvested DM yield from ryegrass pastures was ( $P < 0.003$ ) greater than that achieved on the tall fescue pastures in each of the three years (Table 4.1.); averaging 13.6, 12.7 and 15.7 t DM/ha from CTF, MTF and PR pastures across both sowing dates and irrigation regimes. While DM yield from CTF pastures was usually greater than from MTF pastures ( $P < 0.031$ ) except in the first year of the spring sown (SS) trial (2008/2009) where the yields were similar.

Perennial ryegrass (PR) yield was increased under I+ conditions in all three years compared with I- PR yield, with increases ranging from 0.3 to 5.5 t DM/ha (Table 4.1.). Similarly, CTF yields were usually enhanced under irrigation compared with I-, except in the first year of the SS trial where yield of I- CTF pastures was greater than that of the irrigated pastures. While MTF yield was often lower under I+ than I- conditions. Irrigation interactions ( $P < 0.015$ ) were observed between tall fescue and ryegrass in each of the three years, under I+ DM yield from PR pastures was considerably greater than tall fescue pastures. Under I- conditions PR and CTF DM yield was similar (i.e. average DM advantage of PR pastures over CTF pastures was 3.3 and 0.9 t DM/ha under I+ and I- conditions, respectively).

In the first year of the SS experiment, the addition of a companion species to the sown grasses did not affect total DM yield (SED = 0.5) (Table 4.1.).

In the autumn sown (AS) experiment, however, the addition of a companion species did affect DM yield ( $P < 0.001$ ). Under I- conditions highest yields were achieved with chicory (Ch) > monoculture > red clover (RC) = white clover (WC); an irrigation interaction was also observed ( $P = 0.033$ ) where I+ monoculture pastures yielded the most DM followed by pastures with Ch > RC = WC. In the second year of the SS experiment, the addition of companion species also affected total DM yield ( $P < 0.001$ ). Highest yields were obtained from the monoculture or red clover mixtures, and the lowest from pastures with white clover and chicory companion species, no irrigation interaction was observed.

Perennial ryegrass yield increased from Year one to two on the SS experiment across all pastures types, with the larger gains observed on the irrigated pastures. Similarly, yield from CTF pastures increased with most pasture mixes, except for I-CTF+WC pastures that were reduced by 10.5%. Mediterranean tall fescue pastures increased in harvested DM yield from Year one to two under irrigation but declined under non-irrigated conditions across all pasture mixes.

**Table 4.1.** Total annual yield (t DM/ha) of forage mixtures, showing the difference in yield between irrigated (I +) and non-irrigated (I -) pastures. Percentage change in yield between the two years of the spring sown trial is also given.

	Autumn sowing			(2008 - 2009)			Spring sowing			% change	
	(2007 - 2008)			(2009 - 2010)			(2009 - 2010)			I +	I -
	I +	I -	Difference	I +	I -	Difference	I +	I -	Difference	I +	I -
CTF	14.1	12.4	-1.7	11.3	14.5	3.2	16.9	15.6	-1.3	49.8	7.0
MTF	12.5	12.4	-0.1	11.3	14.3	3.0	13.2	13.5	0.3	16.9	-5.7
PR	17.0	13.3	-3.7	15.5	14.9	-0.6	20.1	17.4	-2.7	29.6	17.2
CTF+RC	13.2	12.1	-1.1	11.3	12.2	0.9	16.4	15.8	-0.6	44.9	29.7
MTF+RC	11.5	12.6	1.1	12.4	13.6	1.2	15.3	12.5	-2.8	23.3	-8.3
PR+RC	15.7	11.8	-3.9	15.6	15.3	-0.3	21.4	17.9	-3.5	37.4	17.2
CTF+WC	13.4	11.7	-1.7	11.9	14.5	2.6	14.1	12.9	-1.2	18.2	-10.5
MTF+WC	12.7	12.3	-0.4	11.6	12.9	1.3	12.1	11.0	-1.1	4.4	-14.1
PR+WC	14.4	12.3	-2.1	14.8	13.3	-1.5	19.1	16.6	-2.5	29.7	24.4
CTF+Ch	14.0	14.6	0.6	11.7	13.5	1.8	15.8	13.6	-2.2	35.1	0.3
MTF+Ch	13.5	13.9	0.4	10.9	12.9	2.0	13.5	12.2	-1.3	24.4	-5.4
PR+Ch	14.8	13.3	-1.5	14.2	13.2	-1.0	20.4	15.0	-5.4	43.5	13.6
SED (treatment comparison)	0.7			0.8			1.0				
SED (within sown grass)	0.7			0.9			0.9				
P (addition)	***			NS			***				

#### 4.5 Seasonal DM yield

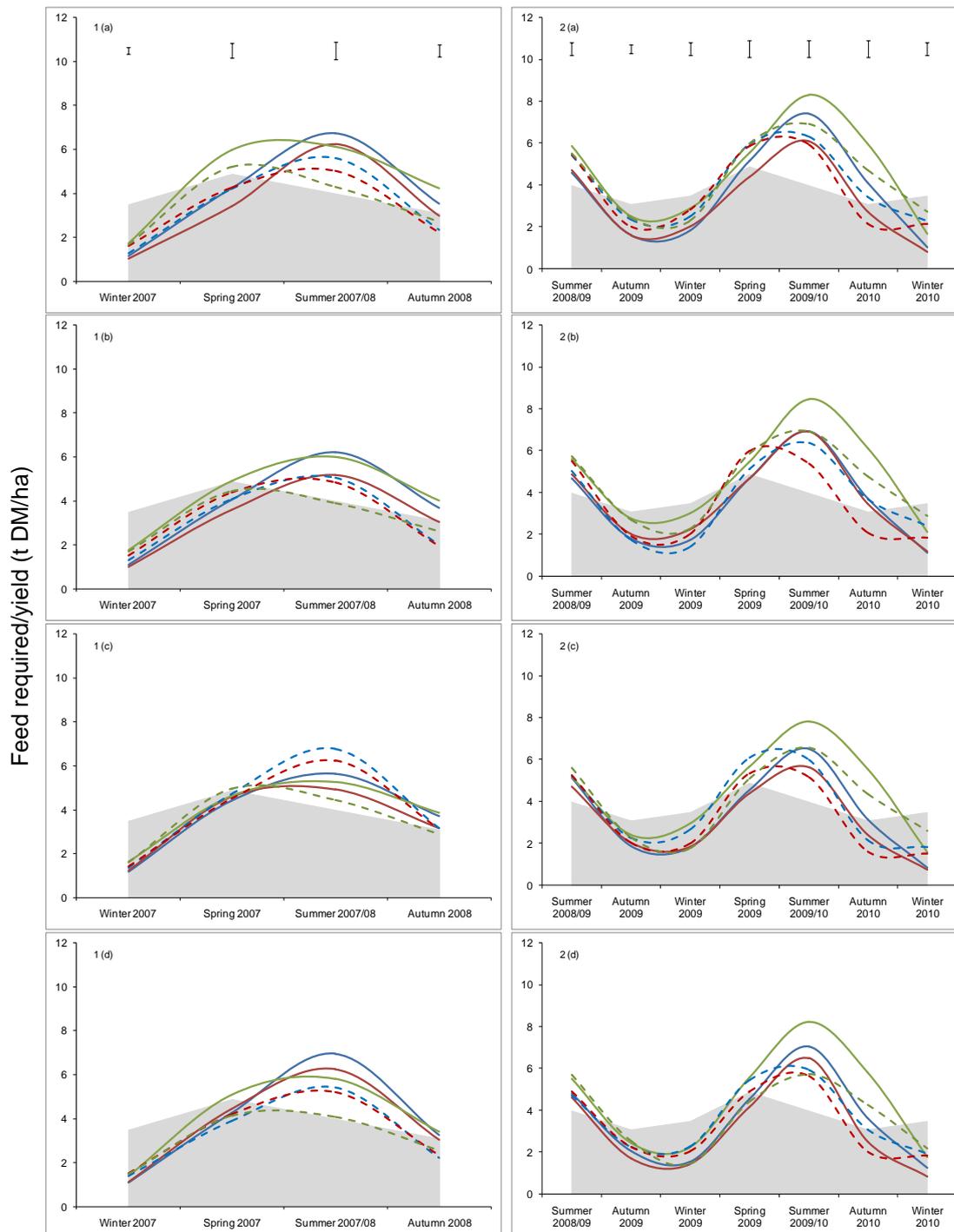
Total harvested DM yield during the establishment period (six weeks post sowing), was greater (0.4 – 0.5 t DM/ha) from the ryegrass pastures than the tall fescue pastures on both the AS ( $P = 0.001$ ) and SS ( $P < 0.001$ ) experiments.

Figure 4.5. describes the seasonal distribution of DM yield from each pasture mix. Seasonal distribution of the sown grass monoculture pastures in the AS experiment showed peak perennial ryegrass production from both I+ and I- pastures in spring, and peak production from the tall fescue pastures in summer. In the SS experiment, peak ryegrass and CTF production occurred in summer from both irrigation regimes. While I+ MTF pastures also peaked in summer, I- MTF pastures peaked late spring. The sown grass in pasture mixes had the largest effect on seasonal DM yields. Where PR pastures showed superior production to tall fescue pastures in all seasons except in summer 2007/2008 where the yield from CTF was greater than from either MTF ( $P < 0.001$ ) or PR pastures ( $P = 0.004$ ). Seasonal yield from CTF and MTF pastures was similar from the start of each experiment until the summer of 2007/2008 and 2009/2010 where CTF pastures were more productive than MTF pastures in those and subsequent seasons ( $P < 0.011$ ).

Sowing mixture affected total herbage yield in the spring and summer of the AS experiment and in all seasons from winter 2009 onward on the SS experiment. In spring and summer of the AS experiment, chicory dominated the tall fescue pastures and contributed up to 40% of the total DM yield from the PR+Ch pasture (Chapter 3; Appendix C); the addition of chicory in the pasture mix increased yield (by up to 7%) relative to the ryegrass monoculture. However, during this period the presence of clover reduced yield (up to 13%) relative to ryegrass monoculture pastures. A grass x species mixture interaction was observed in the spring, summer and autumn where the greatest yields from the fescue pastures were achieved with the inclusion of chicory in the pasture mix. Whereas PR yield was greatest from the monoculture pastures ( $P < 0.015$ ). Across all three sown grasses, an irrigation x pasture mixture interaction was observed in the summer ( $P = 0.011$ ) and autumn ( $P < 0.001$ ) of the AS experiment, where I+ monoculture

pastures produced the most DM, yet under I- conditions pastures containing chicory were superior. In the SS experiment from winter 2009 through to the end of the experiment, either pasture monocultures or red clover mixtures were the most productive, while pasture mixtures with either chicory or clover were the least productive (Figure 4.5.) Irrigation had no effect on pasture mixture DM production in the spring sown experiment.

Perennial ryegrass pastures were the most productive for the majority of the AS experiment and all of the SS experiment, except during the summer of 2007/2008 where CTF pastures outperformed PR pastures under both non-irrigated and irrigated conditions (as mentioned above). Also during summer there was a sown grass x irrigation interaction ( $P = 0.019$ ). Under I- conditions both CTF and MTF pastures outperformed PR pastures at 5.7, 5.3 and 4.2 t DM/ha respectively; while under I+ CTF produced more DM than PR, but PR was more productive than MTF pastures (6.4, 5.8 and 5.6 t DM/ha respectively). In the SS experiment there was no production advantage of tall fescue pastures over ryegrass under irrigation. Under I- conditions however, in winter 2009 production from all sown grasses was similar ( $P < 0.001$ ), and in spring 2009 tall fescue pastures were between 3 – 6% more productive than ryegrass.



**Figure 4.5.** Seasonal yield distribution (t DM/ha) of CTF (blue lines), MTF (red lines) and PR (green lines) pastures from the autumn sown experiment (1) and spring sown experiment (2) relative to the feed requirements (shaded grey area) of a dairy farm stocked at 3.5 cows/ha, adapted from Holmes *et al.* (2007). Yield from irrigated (solid line) and non-irrigated (dashed line) pasture mixtures (a) monocultures (b) sown grass with red clover (c) with white clover and (d) with chicory, is illustrated. Error bars represent SED for all pasture mixes for each season.

#### 4.6 Nutritive value of herbage

Sown grass species affected the nutritive value of the herbage in nearly all seasons. While the effect of species mixture (addition) varied between seasons. Table 4.2. and Table 4.3. describe the nutritive value of the herbage from each pasture mixture in each season. When averaged across all pasture types, the levels of crude protein (CP) were highest in the autumn and lowest in summer of the AS trial and highest in winter and lowest in spring of the SS trial. Levels of neutral detergent fibre (NDF) were greatest in summer and lowest in winter of both trials. While predicted levels of digestibility (organic matter digestibility; OMD) and metabolisable energy (ME) were greatest in the winter of both trials, but lowest in the summer and autumn corresponding with droughts (Figure 4.3. and Figure 4.4.). When differences in CP content were observed, generally pasture mixes with either chicory or a legume contained higher CP content than the monoculture pastures. Monocultures tended to have higher NDF content than the mixtures, with the lowest levels observed on the pastures with chicory in the spring trial. Levels of ME were not affected by pasture mixture in the autumn established trial, however in the spring trial levels of ME and OMD were superior on pastures containing chicory.

Across all pasture mixes and both irrigation regimes crude protein (CP) content was greater (between 1.5 – 5.7%) on the tall fescue pastures than on the perennial ryegrass pastures in nearly all seasons (excluding autumn 2008). While NDF content was greater on the tall fescue pastures in the winter and spring of the autumn experiment, NDF content was significantly higher on the ryegrass pastures in all other seasons of both trials. Generally, there was no measured difference in NDF or CP content between the CTF and MTF pastures except in winter 2009 when CP was greater on CTF pastures than on MTF (28.5 vs. 26.8% from CTF and MTF respectively) and in winter 2007 where MTF pastures contained on average 3.3% more NDF than CTF pastures. Organic matter digestibility and ME content were consistently greater on the ryegrass pastures than on the tall fescue pastures across all seasons; while OMD content of CTF pastures was frequently greater (in 5 of the 8 seasons) or equal to that of the MTF

pastures, ME content was only superior on CTF pastures compared with MTF pastures in summer 2007 and autumn 2009.

**Table 4.2.** Indicators of nutritive value from pasture of each mixture from the autumn sown experiment (2007-2008).

Nutritive value variable §	Winter		Spring		Summer		Autumn	
	I+	I-	I+	I-	I+	I-	I+	I-
<b>CP</b>	----- % DM -----							
CTF	22.3	23.0	21.1	21.1	18.4	17.9	20.7	26.4
MTF	19.2	18.8	19.5	20.0	20.6	16.0	27.5	23.1
PR	22.7	22.6	16.4	14.3	14.9	14.5	23.4	26.1
CTF+RC	22.8	23.7	21.5	22.2	21.2	21.0	25.8	27.5
MTF+RC	20.2	18.2	22.0	19.2	23.0	20.1	27.2	26.6
PR+RC	23.1	22.3	16.7	13.2	16.7	21.2	25.6	26.2
CTF+WC	23.2	22.6	21.9	21.4	22.3	18.6	24.4	26.1
PR+WC	22.5	22.8	19.5	13.7	16.7	14.3	22.5	25.9
MTF+WC	19.8	19.4	23.3	20.4	22.6	19.1	26.9	26.9
CTF+Ch	22.7	22.6	23.8	23.4	21.6	18.5	23.1	24.2
MTF+Ch	19.3	20.2	24.0	22.4	20.8	17.1	25.7	26.8
PR+Ch	22.5	21.7	17.8	17.2	18.4	15.9	23.1	25.7
SED (treatment)	0.4		0.7		0.8		1.2	
P (addition)	NS		**		**		NS	
<b>NDF</b>	----- % DM -----							
CTF	40.8	41.5	48.0	47.3	48.3	47.2	46.2	42.5
MTF	42.2	45.0	48.6	47.2	45.1	47.9	35.0	52.3
PR	39.0	37.9	45.2	44.3	51.7	49.4	44.7	45.6
CTF+RC	38.8	39.7	48.2	44.4	45.0	45.3	38.6	41.6
MTF+RC	44.0	45.1	47.1	46.0	41.8	46.4	37.6	46.8
PR+RC	37.8	38.9	45.1	43.2	49.2	45.4	41.3	45.2
CTF+WC	39.8	40.1	46.7	43.8	40.5	43.6	38.0	40.8
MTF+WC	41.3	43.5	44.0	43.4	39.3	44.9	31.8	43.6
PR+WC	37.7	37.5	45.5	44.7	50.2	47.3	42.0	46.1
CTF+Ch	39.2	39.9	46.5	44.8	47.5	49.0	44.2	46.8
MTF+Ch	43.9	41.4	46.5	45.6	47.8	49.7	42.2	45.4
PR+Ch	39.0	37.2	44.9	46.4	50.0	49.5	45.3	45.5
SED (treatment)	0.7		0.5		0.8		NS	
P (addition)	NS		*		**		NS	
<b>OMD</b>	----- % DM -----							
CTF	86.9	86.0	86.4	89.9	79.1	76.4	78.7	76.1
MTF	86.9	83.8	86.7	88.8	76.3	71.9	86.1	71.6
PR	93.7	94.6	92.0	91.8	81.0	79.9	89.0	87.5
CTF+RC	88.1	86.1	83.4	86.1	76.8	77.3	83.4	80.4
MTF+RC	84.7	83.5	85.2	86.8	78.3	73.6	82.1	75.5
PR+RC	94.9	95.7	92.9	92.0	79.8	82.3	87.7	85.5
CTF+WC	87.5	84.6	86.9	87.5	82.0	77.8	82.5	76.5
PR+WC	96.2	94.2	93.8	91.7	81.1	81.1	89.0	84.9
MTF+WC	86.0	85.8	85.3	88.5	81.1	74.4	86.5	77.6
CTF+Ch	87.9	87.6	85.6	87.1	78.4	77.9	84.7	76.0
MTF+Ch	84.6	85.4	83.9	85.4	79.1	75.3	86.9	82.6
PR+Ch	92.6	93.6	93.8	92.2	81.1	79.1	85.2	84.2
SED (treatment)	0.7		0.5		0.8		1.8	
P (addition)	NS		*		NS		NS	
<b>ME</b>	----- MJ kg/DM -----							
CTF	12.4	12.6	12.2	12.9	11.8	11.5	11.7	11.2
MTF	12.7	12.2	12.4	12.7	11.4	10.7	12.5	10.5
PR	13.6	13.7	13.3	13.4	11.9	11.8	12.9	12.6
CTF+RC	12.7	12.4	12.0	12.7	11.4	11.5	12.2	11.8
MTF+RC	12.3	12.2	12.4	12.7	11.5	10.8	12.0	11.0
PR+RC	13.7	13.6	13.4	13.3	11.8	12.1	12.7	12.3
CTF+WC	12.6	12.3	12.3	12.7	12.1	11.6	12.1	11.2
MTF+WC	12.5	12.4	12.3	12.8	11.9	11.0	12.7	11.4
PR+WC	13.8	13.6	13.4	13.4	11.9	11.8	13.0	12.1
CTF+Ch	12.6	12.7	12.4	12.9	11.7	11.5	12.4	11.0
MTF+Ch	12.3	12.5	12.5	12.6	11.6	11.1	12.7	11.9
PR+Ch	13.4	13.5	13.6	13.2	11.9	11.7	12.3	12.1
SED (treatment)	0.1		0.1		0.1		0.2	
P (addition)	NS		NS		NS		NS	

\* significant at the 0.05 probability level

\*\* significant at the 0.01 probability level

\*\*\* significant at the 0.001 probability level

§ CP, crude protein; NDF, neutral detergent fibre; OMD, organic matter digestibility; ME, metabolisable energy.

**Table 4.3.** Indicators of nutritive value from pasture of each mixture from the spring sown experiment (2008-2009).

Nutritive value variable §	Winter		Spring		Summer		Autumn	
	I+	I-	I+	I-	I+	I-	I+	I-
	% DM							
<b>CP</b>								
CTF	27.1	28.0	24.8	23.2	27.5	25.0	27.1	22.7
MTF	24.4	24.6	24.6	24.3	25.9	25.9	25.1	25.1
PR	26.0	25.1	18.9	16.9	24.9	24.3	20.3	19.9
CTF+RC	29.0	28.4	25.5	23.4	27.4	25.5	27.5	26.2
MTF+RC	26.4	25.6	23.5	23.3	26.9	25.7	26.7	26.5
PR+RC	24.4	23.4	19.8	18.3	24.7	24.2	21.4	21.0
CTF+WC	30.1	29.0	25.9	24.4	27.9	26.8	28.2	25.4
MTF+WC	29.0	28.2	26.0	25.6	27.1	26.0	30.4	25.4
PR+WC	25.9	25.7	20.0	20.2	25.9	25.3	20.9	21.9
CTF+Ch	28.5	27.8	24.4	24.3	27.0	26.3	26.3	25.9
MTF+Ch	27.5	28.3	24.2	22.9	27.9	25.2	27.7	25.3
PR+Ch	27.8	27.3	21.2	22.3	25.7	24.8	23.1	23.6
SED (treatment)	0.3		0.5		0.4		0.8	
P (addition)	***		*		NS		NS	
<b>NDF</b>								
CTF	35.4	38.2	37.3	39.9	41.9	43.6	40.9	46.1
MTF	36.0	39.4	37.5	37.5	43.7	41.7	45.0	45.5
PR	37.3	39.9	39.6	42.0	44.9	43.9	44.3	48.6
CTF+RC	36.3	35.5	38.8	41.0	41.1	43.4	40.7	40.5
MTF+RC	34.1	39.1	39.9	38.4	44.2	42.1	42.3	40.7
PR+RC	36.1	40.4	41.9	41.9	45.0	43.0	44.6	46.1
CTF+WC	29.7	33.4	35.9	36.1	39.2	41.5	37.9	40.3
MTF+WC	31.5	32.5	34.0	35.2	41.5	42.3	34.2	38.3
PR+WC	35.7	35.9	40.0	41.3	43.6	44.4	45.6	44.4
CTF+Ch	30.7	34.6	36.1	33.7	35.0	40.4	33.8	34.0
MTF+Ch	32.4	34.5	37.3	35.8	38.3	38.2	35.3	35.0
PR+Ch	34.5	32.7	39.4	35.5	42.0	43.8	39.3	37.0
SED (treatment)	1.3		0.7		0.4		0.9	
P (addition)	**		**		***		***	
<b>OMD</b>								
CTF	86.5	85.3	86.4	87.2	82.5	83.2	81.4	79.1
MTF	87.0	84.9	85.7	85.8	80.1	84.6	76.7	77.0
PR	93.8	93.1	90.1	90.8	86.8	87.9	86.8	81.8
CTF+RC	86.7	87.9	86.0	86.1	83.1	83.4	81.4	80.9
MTF+RC	86.1	84.5	83.4	84.9	80.6	82.6	77.9	80.0
PR+RC	95.0	90.7	89.7	89.2	87.4	90.8	85.8	84.5
CTF+WC	83.9	83.7	86.2	87.7	85.0	84.9	82.3	84.3
MTF+WC	86.0	84.3	86.5	85.3	83.0	83.7	83.9	82.2
PR+WC	94.8	91.6	92.0	89.6	86.9	88.7	86.5	85.7
CTF+Ch	90.3	90.5	86.8	88.9	86.5	83.8	86.0	88.6
MTF+Ch	90.8	90.9	87.9	86.0	84.2	83.9	84.9	88.1
PR+Ch	94.9	91.5	90.9	90.5	85.4	87.9	85.4	87.7
SED (treatment)	0.7		0.7		0.7		0.7	
P (addition)	**		NS		NS		**	
<b>ME</b>								
CTF	12.7	12.5	12.8	12.9	12.0	12.3	11.9	11.7
MTF	13.2	12.8	12.7	12.9	11.7	12.4	11.4	11.4
PR	13.9	13.5	13.5	13.6	12.6	12.9	12.8	12.1
CTF+RC	12.8	13.0	12.7	12.7	12.0	12.1	11.9	11.9
MTF+RC	12.9	12.7	12.4	12.8	11.8	12.1	11.5	11.8
PR+RC	14.1	13.5	13.4	13.4	12.6	13.2	12.6	12.3
CTF+WC	12.7	12.3	12.7	13.0	12.2	12.3	12.1	12.3
MTF+WC	12.7	12.7	12.8	12.9	12.1	12.4	12.3	12.0
PR+WC	13.9	13.6	13.5	13.5	12.5	12.8	12.8	12.6
CTF+Ch	13.3	13.2	12.9	13.0	12.5	12.1	12.4	13.1
MTF+Ch	13.5	13.4	13.0	13.0	12.2	12.3	12.3	12.9
PR+Ch	13.9	13.5	13.3	13.6	12.3	12.8	12.4	12.9
SED (treatment)	0.1		0.1		0.1		0.1	
P (addition)	**		NS		NS		**	

\* significant at the 0.05 probability level

\*\* significant at the 0.01 probability level

\*\*\* significant at the 0.001 probability level

§ CP, crude protein; NDF, neutral detergent fibre; OMD, organic matter digestibility; ME, metabolisable energy.

## 4.7 Discussion

### 4.7.1 Annual DM yield

Over the three years of this study (March 2007 – November 2010), perennial ryegrass pastures consistently produced more DM annually than the tall fescue pastures under both irrigated and non-irrigated conditions (Table 4.1.). These results support the findings of Allen and Cullen (1975) Parry *et al.* (1992), and Hainsworth *et al.* (1991) who reported a 25% yield advantage of perennial ryegrass over tall fescue pastures in coastal Taranaki, similar to the 15 and 24% average (of 3 years) yield advantage over CTF and MTF pastures, respectively, in this experiment. However, these results are contrary to the original hypothesis and to other research that showed yields up to 133% greater from tall fescue pastures when compared with perennial ryegrass pastures from studies throughout New Zealand (Allo and Southon 1967; Easton *et al.* 1994; Judd *et al.* 1990; McCallum *et al.* 1992; Rollo *et al.* 1998; Thomson *et al.* 1988; Watkin 1975). Although, several of these studies (Judd *et al.* 1990; McCallum *et al.* 1992; Thomson *et al.* 1988) compared newly established tall fescue pastures with resident perennial ryegrass pastures, and as DM production tends to decline with stand age, the results of those studies may not be without bias (Chapter 2).

Yields from MTF pastures were the lowest of the sown grasses investigated in this experiment, and in Year two of the SS experiment a substantial proportion (up to 58%, Chapter 3) of the harvested yield was from weed species. This suggests that MTF is a poor competitor with weeds under dairy cow grazing in the Waikato and is therefore not recommended for use in this area.

A contributing factor to the low annual yield from tall fescue pastures in Year one of both trials was the inferior production from these pastures during the establishment phase. A considerable body of research has also described the slow establishment of tall fescue pastures (Brock *et al.* 1982; Clark *et al.* 2010; Hainsworth *et al.* 1991; McCallum *et al.* 1992; Praat *et al.* 1996), which has been attributed to poor mobilisation of seed reserves, slower germination rate (Charlton *et al.* 1986; Moot *et al.* 2000) and seedling growth (Kemp *et al.* 2001). Despite advances in plant breeding for improved vigour of tall fescue seedlings (Easton and Pennell 1993), the disparity between the early growth of tall fescue and

perennial ryegrass remains, as demonstrated by the low establishment yields measured on this study. Figure 4.6. visually depicts this, showing the much more advanced growth of the perennial ryegrass pastures six weeks post sowing (spring sown experiment).



**Figure 4.6.** Spring sown experiment, showing establishment of tall fescue and perennial ryegrass pastures.

The application of irrigation enhanced the yield of perennial ryegrass pastures by up to 26% (5.5 t DM/ha) relative to the non-irrigated pastures, and is similar to that described by Thom (2001) from irrigated pastures also in the Waikato. While yields from CTF pastures were also enhanced under irrigated conditions in the AS experiment (excluding CTF+Ch pastures) and in the second year of the SS experiment, in both years the magnitude of the increase in DM production was less than that observed on the ryegrass pastures. This contrasts with the findings of Clark *et al.* (2010) who demonstrated that irrigation increased DM yield of CTF pastures by 50%, compared to a 13% increase from ryegrass pastures. However, these findings support those by Rollo *et al.* (1998) who stated that when soil moisture is not limiting ryegrass will produce more DM than will tall fescue. Conversely, in the first year of the SS experiment, DM production from both Continental and Mediterranean tall fescue pastures was enhanced under non-irrigated relative to irrigated conditions. The greatest increases in DM were observed on the CTF monoculture and CTF+WC pastures which correspondingly had higher sown grass tiller densities and a higher proportion of sown species in the sward compared to similar pastures under irrigation (i.e. 72 vs. 60% sown

grass on the non-irrigated and irrigated monoculture pastures respectively; Chapter 3). These results suggest that in the absence of irrigation in the Waikato the competitive ability of tall fescue plants is enhanced. Furthermore the sown grass component of the sward remained higher on the non-irrigated pastures in the second year of the SS experiment than observed on the irrigated pastures (Chapter 3). Tall fescue plants are known to be more vigorous during the warmer months and have the advantage of a good tolerance to low soil moisture. Therefore sowing CTF in spring may contribute to the survival of these pastures, through better establishment. However, this did not lead to larger gains in production from Year one to two as larger increases in annual DM were observed between years on the irrigated pastures relative to non-irrigated.

As mentioned previously, under irrigation the DM production of ryegrass was consistently greater than that of tall fescue. Under non-irrigated conditions, however, the DM production differences between sown grasses were less consistent. Across all pasture mixes, yields of perennial ryegrass and tall fescue pastures were similar in the first year of both the SS and AS experiments under non-irrigated conditions; however, in Year two of the SS experiment yields of ryegrass pastures were above that from tall fescue pastures.

In the first year of the SS experiment, the addition of a companion species did not affect annual DM yield. However in the AS experiment and Year two of the SS experiment the addition of a companion species did affect yield, but the effect was inconsistent. Generally, the addition of a companion species reduced perennial ryegrass yield in the AS experiment but produced similar yields in Year two of the SS experiment. The addition of a legume (red or white clover) reduced CTF yields, suggesting that tall fescue is susceptible to competition from clover. The high clover content observed on this trial and associated reduction in sown grass as reported in Chapter 3 of this thesis supports this suggestion.

The addition of chicory enhanced annual yield of CTF pastures under non-irrigated conditions, and the yield of MTF pastures under both irrigated and non-irrigated conditions in the AS experiment. In all scenarios (irrigation, sowing time) chicory comprised a large proportion of the pasture and thus made a substantial contribution to the total yield, but this was at the expense of the sown

grass (Chapter 3; Appendix C). Similar findings were reported by Lowe *et al.* (2009b) in studies in Australia and Hume *et al.* (1995) in New Zealand. Chicory displays vigorous summer growth; this resulted in a reduction in survival of tall fescue tillers (Chapter 3). Also, as 'Choice' chicory is a biennial species, chicory contribution declined from Year one to two of the spring experiment (Table 3.2.), which allowed for weed ingress resulting in reduced yield in Year two relative to the monoculture pastures. This affect was not observed in the perennial ryegrass pastures, while chicory contributed up to 44% of the total yield in Year one (non-irrigated, SS), the loss of chicory plants in Year two was mitigated by increasing ryegrass tiller density (Chapter 3, Figure 3.3) that reduced weed ingress relative to CTF pastures. These findings support Milne's (1997) statement that if tall fescue does not establish satisfactorily, it will not increase in its contribution to the sward over time unlike perennial ryegrass. Therefore care must be taken when sowing chicory with tall fescue in the spring, and for long term pasture production a seeding rate lower than the one used in this experiment for chicory is recommended, though further evaluation is required.

Neal *et al.* (2009) suggested that it is the year to year stability of pasture production that is the most important commercial factor as it allows for easier on farm management of resources and stable farm production and profitability. Year to year pasture production can be extremely variable, thus the two year spring sown experiment can offer only limited inference of pasture production stability. However, a trend of increasing pasture production from Year one to Year two of the SS trial under irrigation was observed across all pasture types, with gains of up to 50% (Table 4.1) observed on the CTF pastures. In general pastures with the highest increases in DM production were those where sown species maintained dominance in the sward and maintained tiller density. Pastures that showed reduced production from Year one to two (all MTF pastures, CTF+WC and CTF+Ch) had correspondingly low tiller densities and weeds comprising greater than 20% of the pasture (Chapter 3). This trend contrasts with the findings of Minneé *et al.* (2010) in Canterbury that showed that while the production of CTF pastures was more stable than PR pastures, a decline in production over the course of the experiment was still observed, though to a lesser extent than the PR pastures (20 vs. 36% from CTF and PR respectively). Similarly Neal *et al.* (2009)

demonstrated a 46% decline in productivity from ryegrass pastures compared to 20% from tall fescue pastures over a three year study in New South Wales, Australia.

#### 4.7.2 Seasonal DM yield

Over the three years of this study, summer 2008/2009 was the only season where the CTF pastures out-yielded PR, under both irrigated and non-irrigated conditions (Figure 4.5.) by 10 and 36% respectively. This coincided with an extreme drought and higher than average temperatures in the Waikato (Figure 4.3.; Figure 4.4.). A key advantage of tall fescue is its superior tolerance to high temperatures relative to ryegrass. Blaikie and Martin (1987) showed that net photosynthesis of perennial ryegrass declines above ambient temperatures of 18°C. Average air temperatures during January and February 2008 were 20.3 and 19.0°C, respectively, suggesting that ryegrass growth would have been limited by high temperatures during this time, yet as tall fescue is able to grow in air temperatures up to 35°C it is likely to have continued to accumulate biomass. However, a yield advantage of CTF over PR was not observed that same summer from a similar trial conducted in Canterbury (Minneé *et al.* 2010), but irrigation could not be applied over the entire dry period of Minneé *et al.*'s (2010) study reducing the potential CTF production. Furthermore no advantage, either under non-irrigated or irrigated conditions was seen on either summer of the spring sown trial (Figure 4.5.), although during both summers, higher than average rainfall fell in some months which are likely to have promoted PR growth. These results are consistent with those reported by Clark *et al.* (2010) who described a 20% yield advantage of CTF in summer in the first year after establishment, but no difference between CTF and PR pastures in the summer of the following year, indicating that the summer yield response of tall fescue is variable and likely related to soil moisture. This supports the findings of Rollo *et al.* (1998) and Hainsworth *et al.* (1991) who demonstrated that PR production was superior or equal to that of CTF with increased summer rainfall.

The seasonal distribution of growth showed a similar pattern for all pastures (Figure 4.5.). Pasture production peaked in spring and summer and lowest in autumn and winter, similar to that described elsewhere for CTF and PR pastures (Clark *et al.* 2010; Neal *et al.* 2009; Thomson *et al.* 1988). In contrast to the

literature, that describes the main growth period for MTF to be from autumn to late spring (Easton *et al.* 1994; Lamp *et al.* 2001; Reed 1996), peak production of MTF pastures observed in this study was during spring and summer, Appendix C, the latter largely owing to the yield of weed and companion species. These results also support the findings of Neal-Smith and Wright (1969) that showed that in sward conditions the superiority of MTF growth is reduced due to competition from other species. In the spring sown trial, when in pasture mixes, irrigated tall fescue production peaked in summer, whereas non-irrigated pasture production peaked in spring. This may reflect the differences in botanical composition of the sward between irrigated and non-irrigated conditions, where irrigated pastures contained less sown grass with the bulk of the yield coming from the more summer active companion species.

Perennial ryegrass production was consistently superior to tall fescue in winter, as also described by Clark *et al.* (2010). However other studies have shown that CTF production in winter to be comparable to that of PR (Brock 1983; Exton *et al.* 1996; Kerrisk and Thomson 1990; MacFarlane 1990). Clark *et al.* (2010) concluded that PR is likely to have a lower temperature threshold for growth than CTF, although tall fescue is capable of maintain growth to 0°C, and perennial ryegrass ceases growth at 4°C (Anon. 2008). While CTF can maintain production, at temperatures below optimal growth PR may exhibit higher growth rates than CTF. Consideration must also be made to the choice of cultivars used, in this study. Banquet II perennial ryegrass was evaluated which is known to be winter active (Charlton and Stewart 2006), while Advance tall fescue was shown to be one of the least winter productive tall fescue cultivars in a trial evaluating the seasonal production from 10 different tall fescue cultivars in Australia (Callow *et al.* 2003).

In these experiments irrigated PR pastures more consistently met the feed requirements of dairy cattle and were more productive in spring (based on a farm stocked at 3.5 ha) (Figure 4.5.) which is in contrast to the findings of Judd *et al.* (1990). Non-irrigated PR+WC and PR+Ch were the only pastures that did not exceed requirements in the 2007/2008 summer, though all pastures exceeded requirements in all other summers. In autumn, irrigated pastures of CTF and PR commonly exceeded animal requirements, but not under non-irrigated conditions

in autumn 2008, reflecting a residual effect of the summer 2007/2008 drought. Similarly, during the autumn 2010 drought non-irrigated tall fescue pastures did not produce enough to meet feed required, however non-irrigated PR pastures did. These findings do not support those of Judd *et al.* (1990) who found that pasture production from CTF pastures was superior at meeting cows' requirements. Perennial ryegrass surpluses were considerably greater during the warmer months than those from tall fescue pastures, thus allowing for more feed to be conserved and utilised in periods of deficit.

#### **4.8 Nutritive value of herbage**

The seasonal trends in nutritive value from the pastures in this study were similar to those reported by Chapman *et al.* (2008) for perennial ryegrass and tall fescue based pastures. This study also illustrates the impact of seasonal drought on the nutritive value of pastures, as pastures had the lowest quality in hot, dry conditions. Despite the seasonal variation, nutritive value of pastures was largely within the parameters considered to equate to good quality (> 11.5 MJ ME/kg DM, > 75% OMD, 38 – 45% NDF; 24 – 28% CP; Kolver 2000) (Table 4.2. and Table 4.3.). These results confirm Chapman *et al.*'s (2008) findings that the newer varieties of tall fescue are of higher quality than the earlier varieties (i.e. Demeter), and more comparable with that of ryegrass. However, differences in these indicators of feed quality between the pastures evaluated in these experiments did exist (Table 4.2. and Table 4.3.). Crude protein content of the tall fescue forage was consistently higher than that from the perennial ryegrass pastures, both in the monoculture and mixed pastures. These results support Milne *et al.*'s (1997) statement that tall fescue pastures contain more CP than perennial ryegrass, and is both a function of the CP content of the tall fescue itself and that the tall fescue pastures supported a higher legume and chicory content, species' also known to be high in crude protein (Barry and McNabb 1999; Harris *et al.* 1998). Pasture protein content above 18% is required to support lactation (Kolver 2000). Levels of protein fell below this threshold from non-irrigated perennial ryegrass monocultures in spring of the SS experiment, but were elevated through the inclusion of a companion species on all other ryegrass pastures. In the AS experiment, lowest protein concentrations were observed during the summer

2007/2008 drought, with the non-irrigated monoculture pastures all having protein contents below the 18% threshold, but higher levels found on the irrigated pastures which is in contrast to that found by Jensen *et al.* (2007) and Asay *et al.* (2002) who observed increasing CP content with declining irrigation levels. CTF pastures more consistently met lactating cow crude protein requirements during this period. Levels of NDF were also higher on tall fescue pastures compared with perennial ryegrass pastures, which is consistent with that observed on other studies (Callow *et al.* 2003; Lowe *et al.* 2009a). The increase in fibre content likely contributes to the poorer OMD of the tall fescue pastures observed in this study, and corresponding lower ME values for tall fescue pastures relative to perennial ryegrass. The lower ME of the tall fescue pastures was mitigated to a small extent by the inclusion of a companion species, but only in some seasons (autumn and winter of the SS experiment).

In conclusion, annual DM yields were consistently higher from PR pastures than from Continental or Mediterranean type tall fescue pastures under dairy cow grazing and both irrigated and non-irrigated conditions in the Waikato. MTF pastures produced the least DM, of which a large proportion was from either the companion species or weed species. The seasonal spread of DM showed similar patterns between all pastures evaluated in this study, with fescue pastures considerably less productive than ryegrass in the winter and the purported high yielding potential of CTF in the warmer months, seen only in one summer of the three during the experimental period. The application of irrigation boosted both PR and CTF pasture DM yields, but the magnitude in increase was greater from PR pastures, suggesting it is the PR pastures that have the greater water use efficiency in this environment.

Overall the inclusion of a companion species tended to reduce annual DM yields, but maintained or elevated pasture CP content, particularly evident in the summer 2007/2008 drought. Crude protein content was consistently greater on tall fescue pastures, a result of higher companion species content on the fescue pastures but also higher content in the fescue compared to ryegrass; however levels of ME were consistently higher on the PR pastures relative to tall fescue resulting in a greater ME yield per hectare obtained from PR pastures. Therefore, despite the known drought tolerance of CTF pastures, this does not consistently translate to

superior annual DM production relative to PR pastures; however, the elevated CP content of the CTF pastures may warrant their inclusion in farm systems.

#### **4.9 Implications**

In pasture based dairy systems, the amount and quality of the pastures directly influences milk production. Energy is considered to be the most common limiting nutrient for livestock production (Nicol and Brookes 2007). Using the seasonal yield and seasonal ME content of the monoculture pastures in Year one of both experiments in this study, a simple calculation of energy yield per annum was made (Table 4.4.). This shows that the ME yield from perennial ryegrass was superior to that from the tall fescue pastures in both years. Metabolisable energy yield from irrigated pastures was superior to that from non-irrigated in Year one, but in Year two, ME yield from non-irrigated tall fescue pastures surpassed that of irrigated tall fescue which was the result of the weedier and poorer quality pastures under irrigation. Taking an average stocking rate of 3.5 cows/ha, the amount of energy available to the cow can be calculated. Then assuming that an average sized cow (450 kg live-weight) and average milksolids production (400 kg MS/yr) requires 52700 MJ ME/yr for maintenance and production (Nicol and Brookes 2007), it can be determined if these pasture types meet the requirements. Table 4.4. shows that under non-irrigated conditions on the AS experiment all grass types failed to meet the required energy levels. This means that additional feed would have had to be brought into this system or the stocking rate lowered. However, when irrigation was applied, energy yield exceeded that required on the CTF pastures, and a considerable surplus was generated on the PR pasture, but MTF pastures remained in energy deficit. In the SS experiment energy yield from both irrigated and non-irrigated PR pastures exceeded requirement. While irrigated tall fescue pastures were in energy deficit, and again would have required feed to be purchased to supplement or stocking rate adjusted.

**Table 4.4.** Annual metabolisable energy (ME) yield (MJ ME/ha), amount of ME available to an individual cow (based on a stocking rate of 3.5 cows/ha) and the energy deficit or surplus generated from each pasture type (CTF, continental tall fescue; MTF, Mediterranean tall fescue; PR, perennial ryegrass) under irrigated (I +) and non-irrigated (I -) from Year one of the autumn and spring sown experiments.

	CTF		MTF		PR	
	I+	I-	I+	I-	I+	I-
<b>Autumn experiment (2007/08)</b>						
Total annual ME yield (MJ ME/ha)	186829	160584	163710	151017	230044	177313
MJ ME/cow (@ SR <sup>1</sup> : 3.5 cows/ha)	53380	45881	46774	43148	65727	50661
Deficit/surplus ME yield (MJ ME/ha)	680	-6819	-5926	-9552	13027	-2039
<b>Spring experiment (2008/09)</b>						
Total annual ME yield (MJ ME/ha)	161942	202331	156001	202413	220717	213013
MJ ME/cow (@ SR <sup>1</sup> : 3.5 cows/ha)	46269	57809	44572	57832	63062	60861
Deficit/surplus ME yield (MJ ME/ha)	-6431	5109	-8128	5132	10362	8161

<sup>1</sup> SR, stocking rate



## 5 GENERAL DISCUSSION

### 5.1 Introduction

Dry matter (DM) yield and nutritive value of pastures is important to dairy farmers as these directly influence farm production and profitability. The majority of dairy pastures in the Waikato are perennial ryegrass-based and are limited by low soil moisture and high ambient temperatures in summer. Alternative pasture species, such as tall fescue show potential for increasing forage DM yield as they are better adapted to climatic conditions and are more water use efficient than perennial ryegrass under cutting (Martin *et al.* 2008).

The main objectives of this research were to compare the DM production, nutritive value and survival of two types of tall fescue (Continental, CTF; and Mediterranean, MTF) and tetraploid perennial ryegrass (PR) pastures. The underlying hypotheses were that the wider temperature tolerance and deeper root depth of tall fescue plants would result in greater DM yields and enhance survival of tall fescue plants relative to perennial ryegrass plants.

Dry matter yield, nutritive value and sown grass survival were measured from pastures in a one year trial established in autumn 2007, and a two year trial established in spring 2008. Pastures were sown as either grass monoculture or grass-dominant mixtures with either white clover (*Trifolium repens*), or red clover (*Trifolium pratense*) or chicory (*Cichorium intybus*) as companion species. The experimental design was a split block design with two identical small plot experiments either fully irrigated (I+) or non-irrigated (I-) and grazed rotationally with dairy cows.

This chapter summarises the main findings and implications in relation to the main objective of this study (Section 1.2). Areas for future research are also identified.

## 5.2 Plant survival

Pastures show seasonal fluctuations in sown grass tiller density (Chapter 3) and therefore pasture persistence is best inferred by a net change in tiller density at annual intervals (Hernández Garay *et al.* 1997). Over the two year study, averaged across all pasture mixes, only CTF pastures exhibited a positive change in tiller density. Furthermore a greater increase observed under non-irrigated (I-) conditions (i.e. a net gain of 53 vs. 660 tillers/m<sup>2</sup> from irrigated, I+, and I- pastures respectively). While both MTF and PR, pastures demonstrated a negative change in tiller density (-1079 and -614 tillers/m<sup>2</sup> respectively, across both irrigation regimes). Low tiller density, and a low contribution (< 30% of DM) to the pasture of MTF indicates poor survival of MTF in dairy pastures in the Waikato, and indicates poor persistence as it is below the 70% contribution to pasture DM threshold suggested by (Nie *et al.* 2004). Therefore, MTF is not recommended for use as a pasture species to improve pasture persistence in this region. Seasonal fluctuations in tiller density were greater in magnitude from PR pastures compared with tall fescue pastures (up to 7.5 times greater) and were largely associated with periods of hot, dry climatic conditions, as also was observed by previous research (Lowe *et al.* 2008; Nie *et al.* 2004; Thom *et al.* 1998b). The data indicate that PR tiller survival was more sensitive to extreme hot and dry climatic conditions than was tall fescue tillers. However, the death of some PR tillers may be a drought avoidance mechanism (dormancy) employed by the plant for survival (Volaire 1998) as tiller density post-drought was restored to levels observed pre-drought. The use of irrigation reduced the loss of tillers from both PR and tall fescue pastures during droughts, indicating that low soil moisture contributes more to tiller death than does high ambient temperature. The addition of a companion species tended to reduce sown grass tiller density, with the largest declines observed on the pastures sown with chicory. Chicory dominated the pastures in the warmer seasons (summer and autumn). In the spring sown trial, initial sown grass tiller density was significantly reduced when sown with chicory compared to the other species mixtures, whereas in the autumn sown trial, initial tiller density was similar across all mixtures. Furthermore, tall fescue tiller density remained low when sown with chicory, showing that if the establishment of tall fescue is not successful the pasture will not “thicken up” (Milne *et al.* 1997). Yet

perennial ryegrass appeared to have greater capacity to compete with chicory, as PR tiller density increased in these pastures after the initial chicory dominance. These results suggest that for enhanced survival of tall fescue, it should not be sown in mixture with chicory in spring. However, increased clover content in pastures is advantageous as clover is known to increase milk production from dairy cows (Harris *et al.* 1998). The lower competitive ability of tall fescue observed in this study allowed for greater clover content in the tall fescue pastures compared with PR pastures (av. 36% v 6% for TF and PR respectively) which was above the level Thomson (1984) suggested necessary for clover to have a beneficial effect on animal production.

### 5.3 Production

Annual PR monoculture yields, of between 13.3 - 20.1 t DM/ha, were consistently greater than those from CTF and MTF pastures at between 11.3 - 16.9 and 11.3 - 13.5 t DM/ha respectively (Chapter 4). The difference in annual yield between PR and tall fescue pastures was consistent with results previously reported by (Allen and Cullen 1975; Hainsworth *et al.* 1991; Parry *et al.* 1992), but in contrast to other reports that demonstrated a yield advantage of up to 133% from tall fescue pastures compared with resident PR pastures (Judd *et al.* 1990; McCallum *et al.* 1992; Thomson *et al.* 1988). Martin *et al.* (2008) demonstrated that CTF was more water use efficient than PR, producing an additional 1.4 kg DM per mm of water used than PR. However in this study, the response to irrigation was greater from PR pastures than from tall fescue, where irrigation enhanced PR DM production by up to 26% (equating to 5.5 t DM/ha) compared to CTF and MTF pastures that showed both a positive (up to 14% from CTF+Ch pastures) and negative response to irrigation, likely influenced by the higher tall fescue content in the I- pastures. Enhanced production from PR under irrigation compared to tall fescue is consistent with Rollo *et al.* (1998) who showed that when water is not limiting tall fescue will not out-yield ryegrass.

The seasonal spread of pasture supply was similar from all pastures, which was contrary to expected because the main growth season of MTF is typically in the cooler months with degrees of dormancy expressed in summer (Lamp *et al.* 2001).

However, the summer production from MTF pastures was largely from companion species and/or weeds in the pastures. The Waikato region experienced a 1-in-100 year summer drought in 2007/2008, and this was the only season where both I+ and I-CTF pastures produced greater DM yields than the PR pastures, supporting the findings of others that CTF is more heat and drought tolerant than PR (Garwood *et al.* 1979; Lowe and Bowdler 1995). However, in all other seasons, including an autumn drought in 2009, PR production was superior to CTF which is consistent with Clark *et al.* (2010) who found that CTF response to dry conditions to be variable. Consideration must be given to the timing of the autumn 2009 drought, as the lower seasonal DM yield from the CTF pastures would have been exacerbated by the slower establishment of this species and the lower contribution of CTF to the pastures relative to PR (70 vs. 90% respectively). During the cooler months (winter) PR pastures consistently out-yielded tall fescue pastures indicating that PR is more productive at lower temperatures than tall fescue and agrees with Clark *et al.* (2010).

The effect of a companion species was variable, with no effect observed in Year 1 of the spring sown experiment, and inconsistent effects in the other two years. Generally, the addition of a companion species either maintained or reduced DM yield relative to monoculture pastures. The less vigorous nature of tall fescue allowed for a larger contribution to yield from the lower DM content companion species, lowering overall DM yield as tall fescue yield declined. The addition of chicory enhanced DM production on I-CTF and MTF pastures, but this was at the expense of grass yield and resulted in reduced subsequent yields from these pastures. While chicory contributed greatly (up to 44% of DM) to PR+Ch pastures, and as the chicory content declined, PR content increased indicating that PR has superior competitive ability to tall fescue.

#### **5.4 Forage quality**

The nutritive value of all pastures in this study was largely within the parameters considered to denote good quality (Kolver 2000). The negative impact of drought on the nutritive value of forage was highlighted as the lowest levels of nutritive

indicators (i.e. CP, OMD, ME) were measured during periods of low soil moisture and high temperatures.

The ME concentration (MJ ME/kg DM) of tall fescue pastures (mean 12.3) was consistently lower than the ME concentration of PR pastures (mean 13.0), reflecting the lower OMD of the tall fescue pastures (83.6 vs. 88.9% for PR pastures). However, in winter and autumn for the spring sown experiment the inclusion of a companion species elevated the ME of tall fescue pastures to levels similar to those on corresponding PR pastures.

Tall fescue maintained a greater CP concentration (g/100 g DM) both in monoculture (mean 23.2) and in mixed pasture (mean 24.5) than perennial ryegrass pastures (mean 21.5), indicating that CP levels are higher both within tall fescue and as a result of the greater companion species content in the fescue pastures. Levels of protein above 18% are required to support lactation (Kolver 2000), and levels in pastures only fell below this under I- conditions during the summer 2007/08 drought, and from the PR monoculture pastures in spring of the spring sown experiment. Elevated levels of protein under I+ relative to I- condition are in contrast to other researchers that observed no effect of irrigation on pasture quality (Asay *et al.* 2002; Jensen *et al.* 2007).

## **5.5 Implications**

The work undertaken in this study was to evaluate whether tall fescue pastures were a potential alternative to perennial ryegrass-based pastures for increased DM production, forage quality and pasture survival, for use on dairy farms in the Waikato.

Based on the calculated feed requirements of a dairy farm stocked at 3.5 cows per ha (Chapter 4), PR pastures more consistently meet the feed demands of cows throughout the season through superior production in both the warmer seasons (spring and most summers), allowing for more feed conservation for use in periods of low pasture growth, and in the cooler seasons (autumn and winter).

In 2005 the dairy industry set a target to increase dairy farmer profit and create wealth for the New Zealand economy through a 50% increase in productivity by

2015 (Anon. 2005). Luxton (2005) estimated that an annual increase of 3.6% would be required in order to achieve this. Holmes *et al.* (2007) estimated the average production from farms in the Waikato at between 12 - 17 t DM/ha. Results from this study were largely within this range (Chapter 4), except for I+ irrigated tall fescue pastures in Year 1 of the spring trial that were below expectations, reflecting the slow establishment of tall fescue pastures despite being sown in when soil temperatures were increasing. Irrigated PR pastures were the only pastures to exceed the average (mean 20.3 t DM/ha) and only in Year 2, when the pastures were more established.

Specialist pastures of CTF on farm may still be advantageous for superior production in years of extreme drought or on soils of low moisture retention, and for their elevated protein content in dry summers when the protein concentration of perennial ryegrass is low and growth is limited.

## **5.6 Future research**

The variable response of CTF pasture production in summer and under irrigation, plus the trend of increasing CTF tiller density toward the end of the two year spring experiment, signals that further longer term research in the Waikato would assist in the clarification of CTF production and persistence.

The elevated protein levels of the fescue pastures also warrant larger-scale farmlet types investigations with assessment of milk production from tall fescue-based pastures compared with perennial ryegrass, both in the presence and absence of irrigation.

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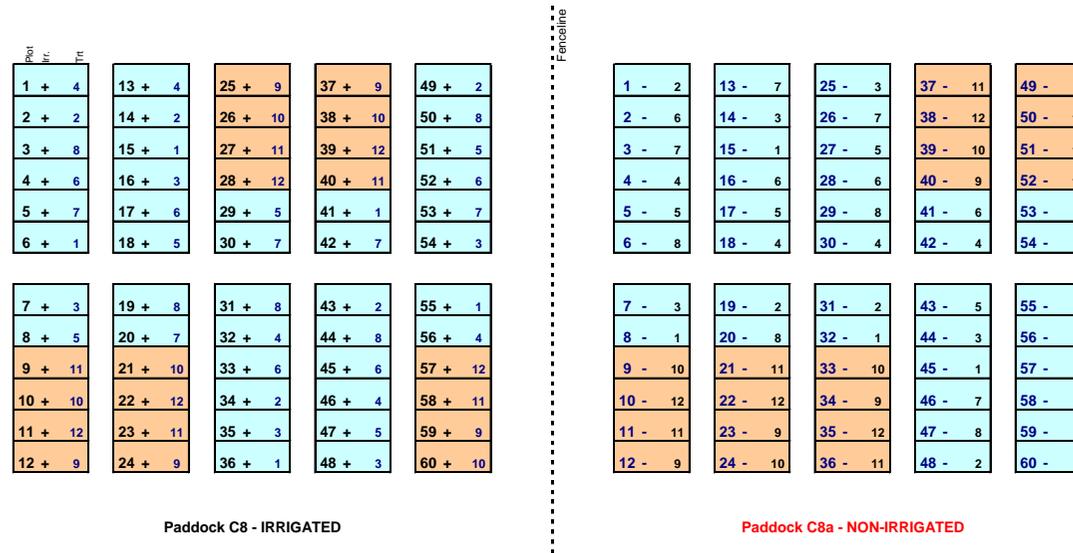
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# APPENDIX A: TRIAL LAYOUT



- Treatments:**
- |    |                                                            |
|----|------------------------------------------------------------|
| 1  | Continental tall fescue monoculture (Advance MaxP™)        |
| 2  | Continental tall fescue + red clover (Colenso)             |
| 3  | Continental tall fescue + white clover (Kopu II)           |
| 4  | Continental tall fescue + chicory (Choice)                 |
| 5  | Mediterranean tall fescue monoculture (Resolute II MaxP™)  |
| 6  | Mediterranean tall fescue + red clover (Colenso)           |
| 7  | Mediterranean tall fescue + white clover (Kopu II)         |
| 8  | Mediterranean tall fescue + chicory (Choice)               |
| 9  | Tetraploid perennial ryegrass monoculture (Banquet Endo 5) |
| 10 | Tetraploid perennial ryegrass + red clover (Colenso)       |
| 11 | Tetraploid perennial ryegrass + white clover (Kopu II)     |
| 12 | Tetraploid perennial ryegrass + chicory (Choice)           |

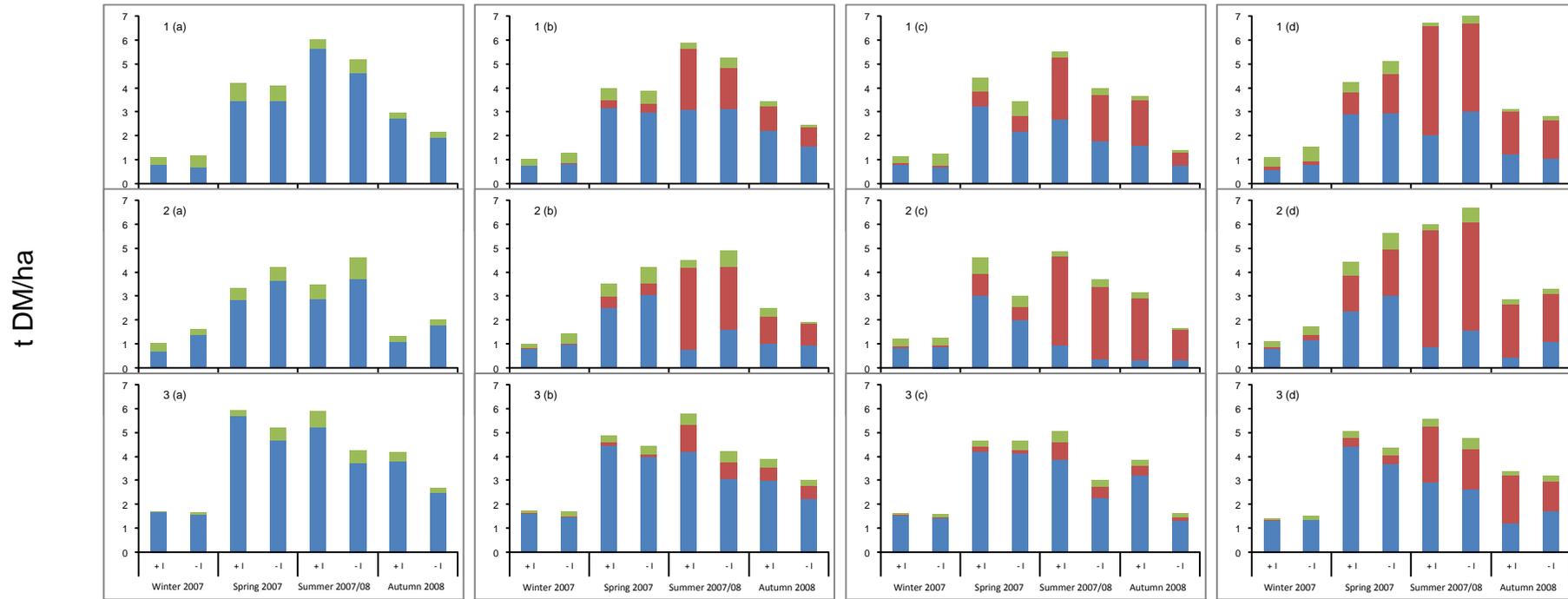
Trial layout depicting separation of irrigated and non-irrigated experiments. Perennial ryegrass (orange plots) and tall fescue (blue plots) pastures were separated by internal fences to allow for independent grazing.

**APPENDIX B: CULTIVAR INFORMATION**

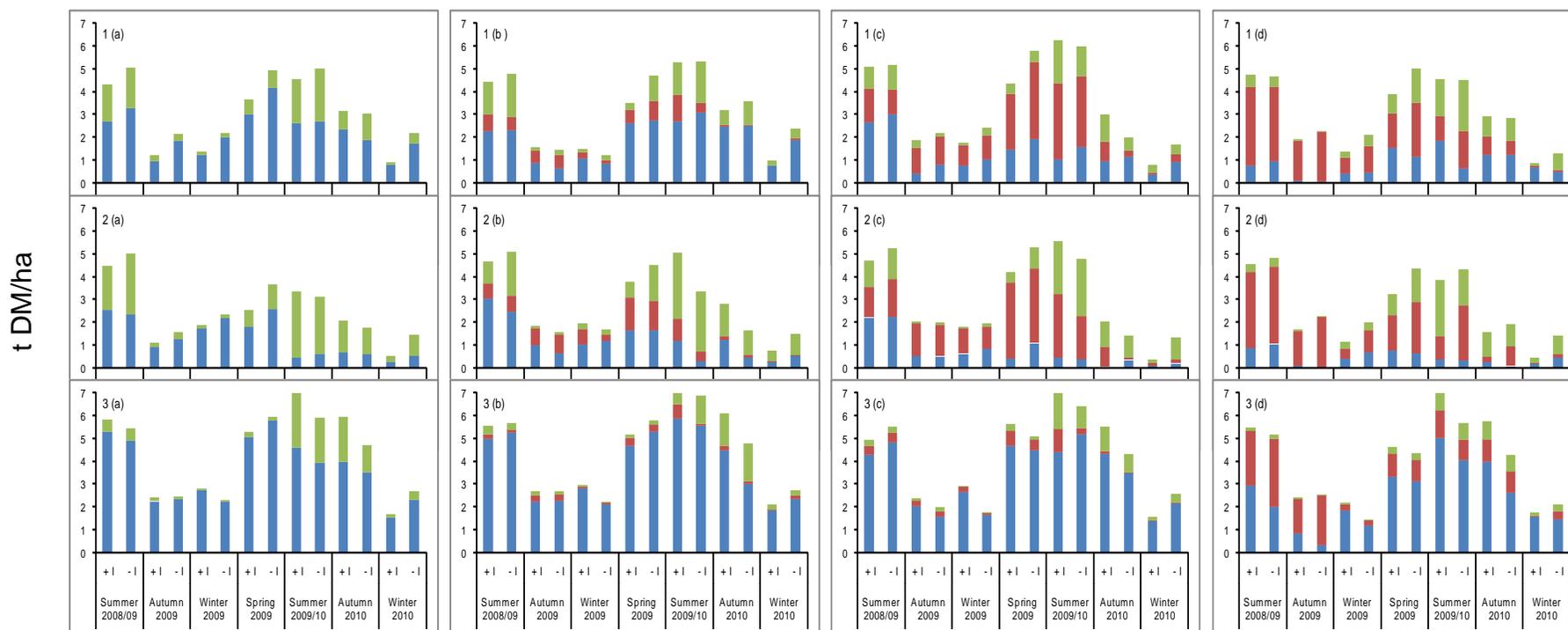
Cultivar, seed line, endophyte and company information for each species.

<b>Species</b>	<b>Cultivar</b>	<b>Seed line</b>	<b>Endophyte</b>	<b>Seed company</b>
Tall fescue	Advance	AVA929AM (autumn trial)  AVA963AP (spring trial)	AR542	PGG Wrightson
Tall fescue	Resolute II	R305KL	AR542	PGG Wrightson
Perennial ryegrass	Banquet II (Tetraploid)		Endo 5	PGG Wrightson
White clover	Kopu II	KO35CP	NA	PGG Wrightson
Red clover	Colenso	CRC45BM	NA	PGG Wrightson
Chicory	Choice	0158/490	NA	Agricom

## APPENDIX C: SEASONAL YIELD DISTRIBUTION



Seasonal yield distribution (t DM/ha) from irrigated (+I) and non-irrigated (-I) pastures of Continental tall fescue (1), Mediterranean tall fescue (2) and perennial ryegrass (3) pastures in monoculture (a), mixed with red clover (b), mixed with white clover (c) and mixed with chicory (d) from the autumn sown experiment (2007-2008). Blue bars denote sown grass, red bars denote companion species and green bars denote weed content.



Seasonal yield distribution (t DM/ha) from irrigated (+I) and non-irrigated (-I) pastures of Continental tall fescue (1), Mediterranean tall fescue (2) and perennial ryegrass (3) pastures in monoculture (a), mixed with red clover (b), mixed with white clover (c) and mixed with chicory (d) from the spring sown experiment (2008-2010). Blue bars denote sown grass, red bars denote companion species and green bars denote weed content.

