# The Response of Selected Temperate Forages to Increasing Summer Drought Conditions and High Summer Temperatures in Northern Victoria, Australia

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## Abstract

In the dairy region of northern Victoria, Australia, the performance of temperate perennial dairy pastures is often poor over summer due to a combination of high temperatures and limited water availability that can restrict dry matter production and plant survival. A series of field experiments examined the effects of heat and restricted irrigation (as a consequence of drought) on the growth and nutritive characteristics of selected forage species, and whether survival under experimental conditions was influenced by plant genotype, irrigation and grazing management strategies, as well as endophyte presence. The major focus was on perennial ryegrass.

Detailed sampling of perennial ryegrass (*Lolium perenne* L.), lucerne (*Medicago sativa* L.) and tall fescue (*Festuca arundinacea* Schreb) pastures on commercial farms during five extreme heat events (>35ºC) over summer 2018/2019, highlighted the impact of high temperatures on pasture nutritive parameters. *In vitro* dry matter digestibility and water soluble carbohydrate concentrations decreased by 0.2% units per degree rise in average maximum daily temperature from 23 to 40 ºC and neutral detergent fibre and acid detergent fibre concentrations increased by 0.2% and 0.15% units per degree, respectively.

When a range of perennial ryegrass cultivars, hybrid ryegrasses and tall fescue cultivars were evaluated under full and restricted irrigation and two grazing strategies, few differences in net pasture accumulation over summer or survival were observed. The research highlighted the importance of maintaining plant density during periods of restricted irrigation to ensure plant recovery once irrigation or rainfall becomes available. No endophyte-ryegrass combinations were found to be better adapted to restricted water and high temperature conditions.

The incidences of extreme heat events and low water availability are increasing in northern Victoria and this research will assist farmers to identify strategies to mitigate the negative effect of these conditions on the production and feed quality of perennial ryegrass-based pastures.

## Introduction

Climate change forecasts for the dairy region of northern Victoria, Australia, predict that mean temperatures will increase by 1.5 to 3ºC, and annual rainfall will decrease by 2 and 5% by 2050, leading to greater evapotranspiration and lower volumes of water available for irrigation in this region (Norton et al. 2016). Traditionally, perennial ryegrass (PRG) has been the major component species used in this region, however PRG is better suited to mild, moist conditions (20-25ºC) (Cooper and Tainton, 1968) and does not perform well under high summer temperatures (>30ºC) (Vough and Marten, 1971, Langworthy et al. 2018,) or when water is limited (Rawnsley et al. 2009, Rogers et al. 2019).

Over the past decade, research undertaken by Agriculture Victoria, Tatura, has examined the effects of extreme heat and limited water on PRG growth over summer to determine strategies that optimise pasture production, survival and nutritive characteristics under these conditions. The research has involved quantifying the effect of extreme heat (>35ºC for at least three days) on the nutritive characteristics of PRG, lucerne and tall fescue pastures, evaluating a range of PRG genotypes and endophyte combinations for their performance and persistence under conditions of summer drought, and investigating irrigation, grazing and pasture renovation strategies that could be used by farmers over summer.

## Materials and Methods

*Experiment 1 – Heat effects on nutritive characteristics of perennial ryegrass*

During late spring, summer and early autumn of 2018/2019 (November – March), forage was sampled on commercial farms during five extreme heat events to evaluate the effects of high temperatures on the nutritive characteristics. Replicated samples of three forage species (perennial ryegrass, tall fescue and lucerne) were taken before, during, and after, a heat event (maximum temperatures above 35ºC). Samples were analysed for *in vitro* dry matter digestibility (IVDMD), water soluble carbohydrates (WSC), neutral detergent fibre (NDF), acid detergent fibre (ADF), crude protein (CP) and important anti-nutritive compounds (alkaloids in perennial ryegrass, and saponins and coumestrols in lucerne).

*Experiment 2 –DM production and survival of genotypes following restricted irrigation over summer*

The responses of ten cultivars of PRG (Avalon, Banquet II, Base, Bealey, Bronsyn, Extreme, Impact, Impact II, One50 and Prospect), three cultivars of hybrid ryegrass (Barberia, Matrix and Shogun), two cultivars of tall fescue (Quantum and Advance) and their associated endophytes to two irrigation strategies (full season irrigation and restricted irrigation – no irrigation between late December and mid-March) were evaluated over summer for three years (Rogers et al. 2019). The suite of PRG cultivars included a range of Spanish ecotypes that have been reported to have superior summer-drought survival (Matthew et al. 2012). Measurements included net pasture DM accumulation (NPA), plant frequency/sward density and water soluble carbohydrate concentration.

*Experiment 3 – Irrigation and grazing management of perennial and short-lived ryegrasses over summer*
An on-farm experiment was established at two sites in northern Victoria in March 2015 and ran for three years. At each site, five PRG (Avalon, Base, Bealey, Impact II and One 50) and two short-lived ryegrass (SLRG) (Barberia and Crusader) cultivars were sown in two irrigation bays (Rogers et al. 2021). The five cultivars were sown in duplicate, with one of the duplicate PRG, and all of the SLRG plots oversown with the original ryegrass in March 2016 and 2017. One bay was not irrigated over summer (late December to mid-March) and the other bay was irrigated once over this period. In the middle of summer, half of each plot was grazed once. Measurements made included NPA, nutritive characteristics, sward density and botanical composition.

*Experiment 4 – Perennial ryegrass and endophyte combinations under limited water.*
Fourteen perennial ryegrass / endophyte combinations, comprising five PRG cultivars (Bealey, LP423, One 50, Reward and Trojan) and nine endophytes (nil, SE, AR37, Endo 5, NEA2, NEA3, NEA10, NEA11 and NEA12) were sown in plots in a randomised complete block design at the Agriculture Victoria Tatura Centre. There were two irrigation strategies – full irrigation and restricted summer irrigation (no irrigation from December to March). Measurements made included NPA, endophyte frequency and alkaloid concentrations in tiller bases.

**Results**

*Experiment 1*
Severe heat events reduced IVDMD and WSC and increased NDF and ADF concentrations in all species. For all species, both IVDMD and WSC concentrations decreased by 0.2 percentage units while NDF and ADF concentrations increased by 0.2% and 0.15% units, respectively, for each degree rise in three-day maximum temperature. Concentrations of the alkaloid ergovaline in tiller bases were above threshold levels for negative animal welfare outcomes (0.4 mg/kg) on two occasions (14 January – 0.48 mg/kg and 21 January – 0.41 mg/kg) when the three-day maximum temperatures were 40.7ºC and 33.5ºC, respectively. Ergovaline concentrations in the leaf blades were always less than 0.07 mg/kg. Concentrations of coumestrols and saponins in lucerne did not appear to be affected by high temperatures.

*Experiment 2*
Plant frequency declined significantly under restricted irrigation (shown in Figure 1 for Year 1) but there were no differences between PRG cultivars. Annual NPA over the three years was reduced by over 35% ($P<0.05$) in the restricted compared with the full irrigation treatment (8.5 vs. 12.9 t DM/ha) due to an 85% reduction in summer NPA (0.6 vs 3.7 t DM/ha), a 40% reduction in NPA in autumn once irrigation recommenced (1.2 vs 2.0 t DM/ha) and a 10% reduction in NPA in winter/spring (6.8 vs 7.5 t DM/ha). There were few differences in NPA among PRG or hybrid ryegrass cultivars (data not presented).

*Experiment 3*
There were significant variations across sites, seasons, genotypes and irrigation and grazing management strategies. Net pasture DM accumulation from the SLRGs was significantly less than NPA from the PRG (viz. cumulative production of 16.9 t DM/ha vs 19.7 t DM/ha over the duration of the experiment). Measurements of plant frequency indicated large differences between the perennial and short-lived cultivars (viz. 79% plant presence for perennial cultivars compared with 33% for the short-lived cultivars across both sites and years) and some differences between the perennial cultivars (Table 1). In the non-irrigated plots in 2016, plant frequencies were marginally, but significantly, higher in the plots that had been grazed during mid-summer compared with those that had not been grazed (63% vs 60%) whereas, for the irrigated plots, the reverse occurred (75% vs 77%). Summer NPA was very low (range 0.4 to 2.9 t DM/ha) and plots not

grazed during summer produced more dry matter in the following cooler period than the grazed plots at least in the first year (viz. 9.22 vs 8.88 t DM/ha).

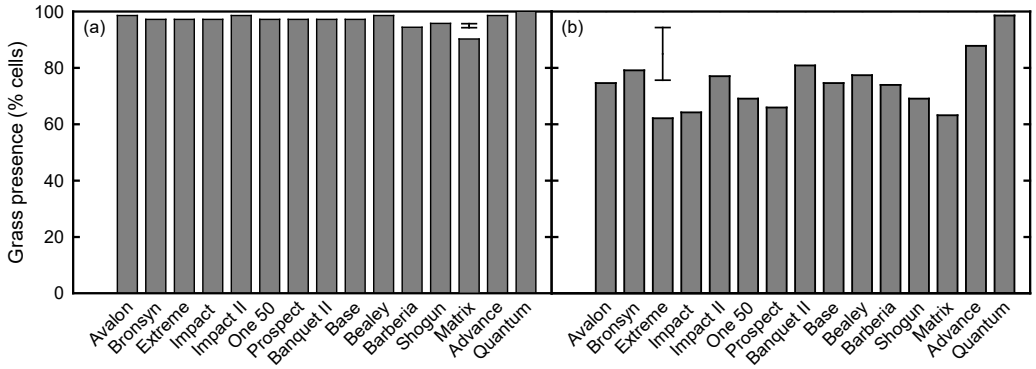


**Figure 1 -Experiment 2.** Grass presence as a percentage of cells in either the full (a) or restricted (b) irrigation bays on 30 March 2016. Vertical bars are between cultivar l.s.d. (*P*=0.05).

*Experiment 4*

There were no significant differences in NPA between any of the genotype-endophyte combinations in either the full or the restricted irrigation treatments. Similarly, there were no differences in alkaloid concentrations between irrigation treatments or plant genotypes. Peramine concentrations ranged from 0.6 to 12.4 mg/kg DM and ergovaline concentrations ranged from 0.1 to 0.4 mg/kg DM.

Table 1. Experiment 3. The effect of irrigation on plant frequency (% presence) for the three different ryegrass groups in Autumn 2016 and 2017.

| | Autumn 2016 | | Autumn 2017 | |
|---|---|---|---|---|
| Cultural group | Dry | Irrigated | Dry | Irrigated |
| Short-lived ryegrass | 20 | 39 | 36 | 38 |
| Perennial ryegrass | | | | |
| not oversown | 75 | 85 | 64 | 73 |
| oversown | 65 | 82 | 69 | 71 |
| Chi probability | 0.089 | | 0.042 | |
| Lsd (P=0.05) | | | | |
| Within irrigation | 8 | | 7 | |
| Between irrigation | 19 | | 20 | |

## Discussion and conclusions

This series of experiments confirm that PRG is not well suited to the current hot, dry conditions of northern Victoria, let alone the high summer temperatures that are projected to become more extreme and frequent in the future.

Plant nutritive characteristics were significantly reduced by high summer temperatures in all three temperate forage species studied in Experiment 1. *In vitro* dry matter digestibility has been observed to decline at high temperatures in other studies (for example, Le Gall et al. 2015), corresponding to lower metabolisable energy concentrations, which can then have negative effects on animal performance. The alkaloid ergovaline in the leaf bases in both Experiment 1 and 4 was close to, or above, threshold levels advised for animal health and welfare to prevent disorders such as ryegrass staggers and heat stress (Moate et al. 2012). Any potential effects of ergovaline on the cows grazing these pastures will depend upon the proportion of leaf blade versus tiller bases in the diet, and the proportion of PRG in the overall animal diet.

Net pasture DM accumulation and plant density in PRG decreased under conditions of restricted irrigation in Experiments 2 and 3. The combined stresses of heat and drought are known to be more detrimental to plant

growth than either stress alone (Langworthy et al. 2018) suggesting that irrigation may assist temperate plants such as PRG to better survive heat stress by maintaining leaf water status and photosynthesis (Perera et al. 2019). This mitigating effect of irrigation was observed in Experiment 2. However, in Experiment 3, where there were a range of other influences (site, grazing and oversowing), the influence of irrigation management appeared to be more complex. When perennial ryegrass plants are moisture-stressed they are generally more vulnerable to the effects of grazing resulting in fewer surviving plants than when they are ungrazed (Waller et al. 2001).

Perennial ryegrass performed better than the short-lived ryegrasses, particularly in terms of plant density or frequency, however, there were no clear effects of specific PRG genetic background on NPA and survival over summer. The presence of endophyte was not found to provide any benefit in terms of NPA to plants undergoing water stress.

In conclusion, it was difficult to identify any irrigation, grazing management or plant genotype effect that could consistently improve the performance of PRG in the hot, dry summers of northern Victoria, Australia. Dairy farmers may need to explore other options such as alternative, semi-tropical and heat-adapted species, or forage options such as grain and silage to feed their cows over summer in this region.

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