## Comparative water use productivity of forages for the dairy industry in northern Victoria

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### Abstract

The dairy industry in northern Victoria uses more than half the irrigation water in the Goulburn Murray Irrigation District, mainly for growing pasture. However, there are few data comparing the water use productivity (WUP) of forage systems under similar management and weather conditions. These data would be useful for dairy farmers aiming to optimise their forage production under conditions of limited water availability. An experiment was established in autumn 2004 with the aim of comparing the dry matter production, water use and WUP of 7 forage systems. The forage systems were: perennial ryegrass/white clover, tall fescue/white clover, lucerne, double crop (oats and millet), Persian clover/Italian ryegrass, subterranean clover/Italian ryegrass and a spray irrigated subterranean clover/Italian ryegrass. The forage systems were mostly border-check irrigated and the forages were grazed and/or mown for hay, using best management practices. Dry matter production, forage nutritive value (metabolisable energy, crude protein and neutral detergent fibre), water use and soil water content were measured, and evapotranspiration was modelled. Water use productivity for the winter-growing annual forages was higher than for the summer-growing and perennial forages. These differences in WUP were larger when calculated using only irrigation water applied than when rainfall was included. Comparison of modelled and measured changes in soil water deficits indicated that FAO-56 crop-coefficients needed little modification for local conditions.

### Key Words

forage production, nutritive characteristics, water use, water use productivity, crop coefficient

### Introduction

The dairy industry in northern Victoria is aiming to increase forage production per unit of water used [water use productivity (WUP)] due to limited water availability and the rising cost of water. Changing the mix of forages grown may increase WUP. While there is some data available on the WUP of forages for dairy production, there are few data comparing the WUP of forage systems under similar management and weather conditions (Greenwood 2003). Comparative data on the WUP of different forages would be useful to dairy farmers aiming to optimise their forage production under conditions of reduced water availability.

Pasture is the cheapest and main source of energy for many dairy cows in the northern irrigation region of Victoria (Doyle *et al*. 2000). Perennial pastures, consisting of perennial ryegrass, white clover and paspalum, are the main pasture type grown for dairy cows. Irrigated annual pastures (including subterranean clover or Persian clover mixed with short-lived ryegrass), occupy about 20–30% of the total irrigated pasture area used by the dairy industry (Armstrong *et al.* 1998). The area sown to lucerne and maize comprises <2% of the milking area (Armstrong *et al.* 1998). Intuitively, annual pastures which grow from autumn through to spring, should have a higher annual WUP than perennial pastures (Doyle *et al.* 2000). However, a survey found that farms with higher proportions of perennial pasture had higher WUPs (Armstrong *et al.* 1998). Hence, there is a need to compare the WUPs of forages used by the dairy industry.

This paper reports on an experiment which aimed to measure and compare the production, nutritive characteristics and water use of a range of irrigated forage species used by the dairy industry in northern Victoria. Preliminary results of modelling the daily water use of one of these forages are included.

## Methods

*Site setup and treatments*

The experiment was conducted at Kyabram in northern Victoria on a red sodosol (Isbell 1996). The experimental site was sown in autumn 2004. The annual and perennial forage systems compared were: perennial ryegrass/white clover (PRG/WC), tall fescue/white clover (TFes/WC), lucerne, Persian clover/Italian ryegrass (irrigated from mid February to late November) (PC/IRG), subterranean clover/Italian ryegrass (irrigated from early March to late October) (SC/IRG), spray irrigated subterranean clover/Italian ryegrass (Spray), and doubled cropped forages (DCrop) which included forage oats (irrigated from late March to mid October) and millet (irrigated from early November to early March). All treatments were irrigated using a border-check (flood) system unless otherwise specified. The experimental design was a randomised complete block with 4 replicates. The plots were 9 by 90 m.

*Management*

The forages were grazed, irrigated and fertilised according to best management practices specific for each forage system. All forages were irrigated when cumulative evaporation exceeded rainfall (E-R) by 50-60 mm, except lucerne (E-R of 100-120 mm) and Spray (E-R of 25-30 mm). Nutrient management aimed to minimise nutrient limitations to forage production while remaining commercially relevant. The perennial pastures (PRG/WC and TFes/WC) were grazed throughout the year and millet through summer. The cool season forages (PC/IRG, SC/IRG, Spray and Oats) were grazed during autumn and winter and made into hay or silage in spring. The lucerne was cut for hay throughout the year.

*Measurements*

Measurements include harvested dry matter (DM), forage nutritive value [*in vitro* DM digestibility (DMD) (Clarke *et al.* 1982), crude protein, and neutral detergent fibre (NDF) (Van Soest *et al.* 1991)], water use (irrigation, rainfall and runoff – irrigation and runoff were measured using flow meters) and soil water content (neutron probe). Metabolisable energy (ME) content (MJ/kg DM) was calculated from DMD (% DM) by the formula ME = 0.17 x DMD – 2.0 (SCA 1990). The values reported are DM-weighted averages.

Water use productivity (forage output/water input) for each forage was calculated using either annual DM removal (t DM/ha) or annual ME removal (MJ/ha). Water input (mm) was calculated using both irrigation water or total water (irrigation plus rainfall less runoff) applied.

Local climatic data was used to calculate reference evapotranspiration using a modified Penman-Monteith equation (Allen *et al.* 1998). Water use and soil water deficits (SWD) were modelled using FAO-56 – Annex 8 (Allen *et al.* 1998) using the dual crop coefficient approach. Modelled and measured SWD were compared.

## Results and Discussion

Total annual forage DM production was lower for the SC/IRG and Spray systems than for the other forage systems (Table 1). The proportion of the DM removed that was conserved was approximately 50% for the annual pastures (PC/IRG, SC/IRG and Spray), 70% for oats, 0% for millet and 100% for the lucerne.

**Table 1. Forage removed, water use and water use productivity (WUP) in 2005**

| | Forage removed | | Water applied (mm) | WUP (kg/ha/mm) |
|---|---|---|---|---|
| | Total | Conserved | | |

| Forage treatment | (t DM/ha) (A) | (% total) | Irrigation (B) | Total (C)[1] | Irrigation (A/B) | Total (A/C) |
|---|---|---|---|---|---|---|
| **Perennial ryegrass / white clover** | 14.9 | 0 | 840 | 1250 | 18 | 12 |
| Tall fescue / white clover | 16.5 | 0 | 870 | 1290 | 19 | 13 |
| Lucerne | 17.5 | 100 | 710 | 1130 | 25 | 16 |
| Persian clover / Italian ryegrass | 15.9 | 44 | 460 | 920 | 35 | 17 |
| **Sub clover / Italian ryegrass** | 10.3 | 46 | 340 | 770 | 31 | 13 |
| **Sub clover / Italian ryegrass (Spray)** | 11.6 | 54 | 300 | 770 | 39 | 15 |
| Double crop - total | 18.2 | 37 | 780 | 1200 | 23 | 15 |
| Lsd (*P*=0.05) | 1.18 | | 60 | 65 | 3.3 | 1.4 |

[1] irrigation plus rainfall less runoff from rainfall. Rainfall was 477 mm. Runoff ranged from 0-70 mm.

Irrigation water use was closely related to the length of the growing season, being greater for the perennial and DCrop systems (710-870 mm) than for the annual pastures (300-460 mm) (Table 1). Runoff from rainfall ranged between 0 mm for the Spray system to 55-70 mm for the perennial and DCrop systems (data not shown). Consequently, the differences between the systems in total water use (irrigation plus rainfall less runoff from rainfall) were relatively similar to differences in irrigation water use.

Water use productivity for the winter-growing, annual systems was higher than for the DCrop and perennial systems (Table 1). However, these differences in WUP were larger when calculated using only irrigation water applied than when rainfall and runoff were included. We expect that WUP measured in following years will differ due to seasonal differences in forage production and water use.

The nutritive characteristics of the SC/IRG and Spray systems (Table 2) were lower than typically reported for annual pastures (Stockdale 1992), a result of the fact that around half of the DM removed was conserved. The amount of ME removed per unit irrigation water used was greater for the winter-growing, annual systems than for the DCrop and perennial systems. However, when rainfall and runoff were included, the amount of ME removed per unit water used was greater for PC/IRG than for all of the other systems.

**Table 2. Forage nutritive characteristics [metabolisable energy (ME), crude protein and neutral detergent fibre (NDF)] and energy removed in 2005**

| | ME | Crude Protein | NDF | Metabolisable energy removed | |
|---|---|---|---|---|---|
| | | | | Total | Per unit water |

| | | | | | (MJ/ha/mm) | |
|---|---|---|---|---|---|---|
| Forage treatment | (MJ/kg DM) | (% DM) | (% DM) | (000 MJ/ha) (D) | (Irrigation)[1] (D/B) | (Total)[2] (D/C) |
| **Perennial ryegrass / white clover** | 12.2 | 18.4 | **43** | 182 | 216 | 145 |
| Tall fescue / white clover | 12.3 | 25.1 | 37 | 203 | 235 | 159 |
| Lucerne | 10.2 | 22.9 | 37 | 179 | 254 | 159 |
| Persian clover / Italian ryegrass | 12.1 | 23.0 | 32 | 193 | 423 | 210 |
| **Sub clover / Italian ryegrass** | 10.3 | 18.3 | 40 | 107 | 318 | 134 |
| **Sub clover / Italian ryegrass (Spray)** | 10.5 | 18.7 | 40 | 121 | 406 | 156 |
| Double crop – total | 10.4 | 10.9 | 58 | 189 | 242 | 158 |
| Lsd (*P*=0.05) | 0.19 | 1.33 | 1.7 | 13.4 | 39.0 | 16.9 |

[1] irrigation water only – see Table 1
[2] total (irrigation plus rainfall less runoff) water – see Table 1

The crop coefficient curves generated for PC/IRG using FAO-56 (Allen *et al*. 1998) are shown in Figure 1. Where the actual crop coefficient (Kcb + Ke) is greater than the basal crop coefficient (Basel Kcb), the difference is the magnitude of the coefficient for soil evaporation (Ke). (Kcb + Ke represents the transpiration plus evaporation components while Basel Kcb primarily represents the transpiration component of crop evapotranspiration). Periods where the Kcb + Ke is less than Basel Kcb indicate times when the crop's evapotranspiration was reduced below potential due to soil water stress. There were no periods of prolonged or severe water stress.

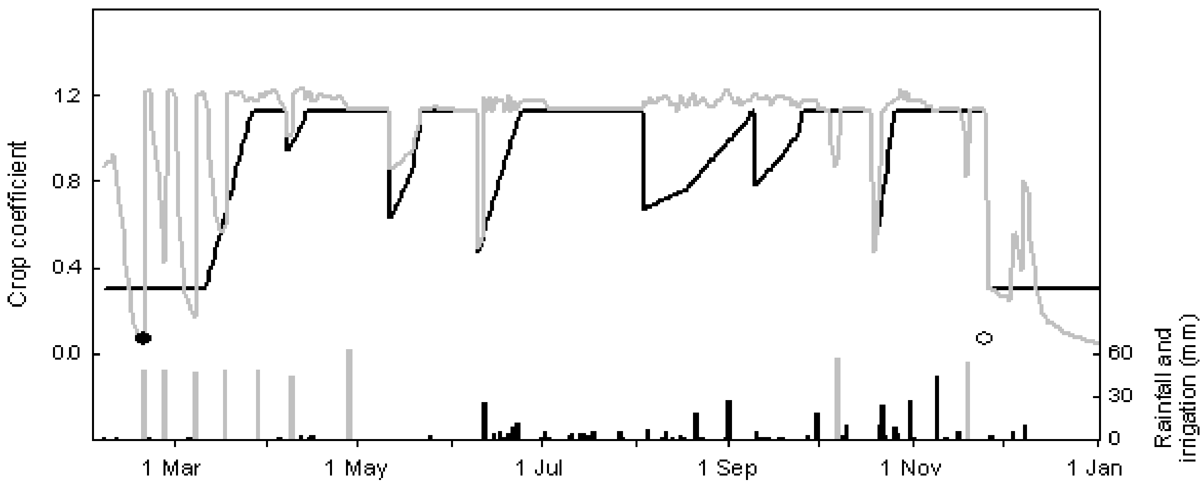


**Figure 1. Crop coefficient curves (Basel Kcb – black, Kcb + Ke –grey) generated by FAO-56 for PC/IRG. Sowing (•) and final harvest (○) dates are indicated. Rainfall (black) and irrigation (grey) quantities are shown as columns.**

Modelled SWD under PC/IRG fluctuated between 0 and 60 mm during its growing season (Figure 2). With border-check irrigation, it is expected that the SWD will be 0 mm immediately after irrigation. The linear regression between the modelled (*y*) and measured (*x*) SWD was

$y = 0.94x - 0.5$ ($r^2 = 0.92$, n=19).

This good agreement between modelled and measured values indicates that the basal crop coefficients provided, and adjusted for local weather conditions as described by Allen *et al.* (1998), are suitable for predicting crop water use (evapotranspiration) in northern Victoria.

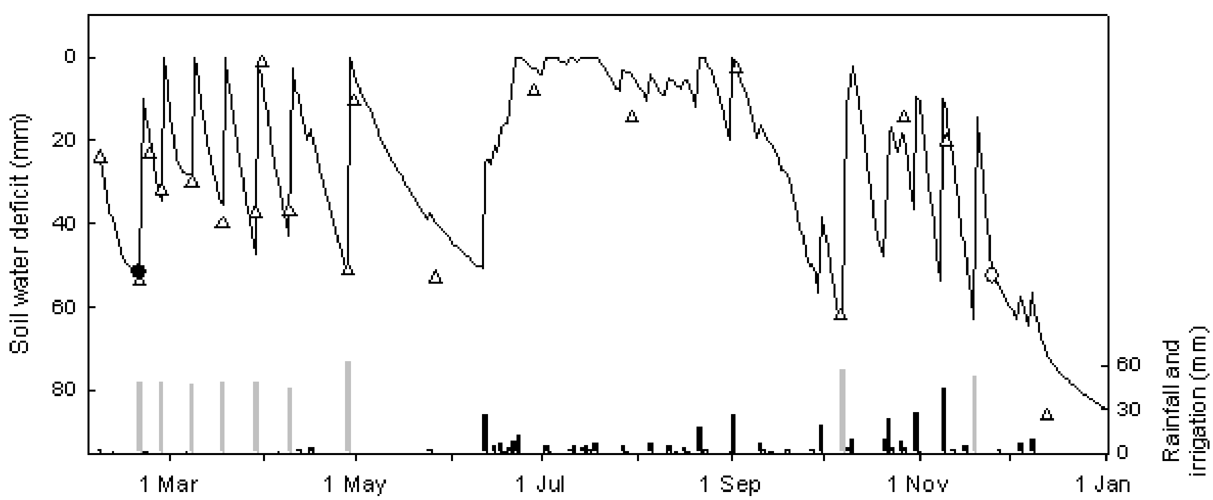


**Figure 2 Modelled (-) and measured (∆) soil water deficits for PC/IRG. Sowing (•) and final harvest (○) dates are indicated. Rainfall (black) and irrigation (grey) quantities are shown as columns.**

**Conclusions**

Water use productivity for the winter-growing, annual forages was higher than for the summer-growing and perennial forages. These differences in WUP were larger when calculated using only irrigation water applied than when rainfall was included. However, other factors such as the nutritive characteristics of each forage (ME, CP and NDF), growing, conservation and feeding out costs, and how well each forage fits a farmers system, also need to be considered by farmers and their advisers. Comparison of modelled and measured changes in SWD indicated that published crop-coefficients needed little modification for local conditions. This approach may therefore be used to model crop water use over a range of climatic conditions.

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