Water application strategies for lucerne

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Abstract
Lucerne is grown in northern Victoria under both dryland and irrigated conditions. The variable irrigation water allocations in recent years has meant that dairy farmers are considering irrigating lucerne (*Medicago sativa*) when irrigation water is readily available and treating it as a dryland crop when irrigation water is scarce and expensive. An experiment was established in 2009 to determine the forage yield and water-use of lucerne under a range of irrigation water application strategies ranging from fully irrigated each year, not irrigated for part of some years, to dryland (i.e. not irrigated) for either 1 or 2 consecutive years. All treatments were flood (border-check) irrigated. The first year (2009/10) saw close to average rainfall and large treatment differences in total water-use (defined as irrigation plus rainfall plus soil water less runoff) (8.0-15.1 ML/ha) and yield (5.0-15.5 t DM/ha). Record irrigation season rainfall in the second year (2010/11) resulted in little difference in either total water-use (10.5 vs. 12.7 ML/ha) or yield (12.5 vs. 14.1 t DM/ha) between the most extreme irrigation treatments. Rainfall in the third year (2011/12) was 10% above average and resulted in large treatment differences in total water-use (5.9-12.9 ML/ha) and yield (5.2-16.9 t DM/ha). The close relationship between forage yield and total water-use has resulted in little difference between the treatments in total water productivity in any given year, provided that the swards were well-watered until late spring. The experiment is scheduled to run for another two years, during which time a fuller picture of the impact of the intermittent irrigation of lucerne should emerge.

Key Words
variable irrigation, flexible forage production, water-use efficiency

Introduction
The dairy industry in northern Victoria relies on irrigation water to grow a large proportion of its feed inputs. However, over the last 15 years, irrigation allocations have been substantially lower and more variable than for the preceding 20-30 years. One option for dairy farming businesses to remain viable in these circumstances is to grow areas of lucerne (*Medicago sativa*) rather than perennial pastures based upon perennial ryegrass (*Lolium perenne*) as it yields well under irrigation, persists in dry conditions and is likely to respond when water is again available. Lucerne, when fully irrigated and cut for hay or silage, can yield 17-26 t dry matter (DM)/ha/year) (Greenwood et al. 2006) with most production occurring during the hotter seasons. Under dryland conditions, the density of lucerne is usually much lower, but annual yields up to 11 t DM/ha are still possible (Hirth et al. 2001). However, there is little information on how quickly lucerne density declines without irrigation, as well as its subsequent productivity after a prolonged period of water stress. The aim of this research is to compare the DM yield and water-use of lucerne under a range of irrigation treatments that might be imposed by dairy farmers when faced with variable water allocations. This paper presents the results from the first three years of a five year experiment.

Methods
This experiment is being conducted at the Department of Primary Industries, Tatura Victoria (36°26' S, 145°15' E, elevation 110 m) on a red sodosol (Isbell 1996). SARDI 7, a winter-active lucerne was sown at 20 kg/ha into a prepared seedbed on 1 May 2009 and then irrigated. Irrigation treatments commenced in spring 2009 and the experiment is planned to continue until autumn 2014.

Experimental treatments
The experimental treatments are:
- Full irrigation (Full)
- Dry autumn - full irrigation until a harvest in January in Years 1, 2 and 3 and then dryland for the remainder of that growing season (D A 1,2 &3)
- Dry summer and autumn - full irrigation until a harvest in November Years 2 and 3 and then dryland for the remainder of that growing season (D SuA 2&3)
- Dryland for one year in Year 1 (D 1) (a single spring irrigation was used to assist establishment), and
- Dryland for two consecutive years in Year 2 and 3 (D 2&3).

All treatments were fully irrigated at other times using flood (border-check) irrigation at intervals of 75-90 mm cumulative daily evaporation less rainfall. Plot dimensions were 12 x 70 m.

Plant measurements
Lucerne treatments were harvested to a height of 60 mm when there were new shoots at the base of the crown which were less than the cutting height of 60 mm (Bourchier 1998). At each harvest, three swathes (1.1 m wide by approximately 6 m long) were cut from each plot, using an autoscythe. The cut swathes were weighed and a subsample taken for dry matter determination.

Soil measurements
Samples for soil chemical analyses (0-100 mm depth) were collected from each plot in early October each year, commencing 2009. Fertiliser rates were determined with the aim of maintaining Olsen phosphorus (P) levels at greater than 25 ppm.

Water measurements
The depth of the local groundwater table is measured using a testwell installed in each plot. The volume of irrigation water applied and runoff were measured from each plot at each irrigation, and following heavy rain, using flow meters. (Runoff water was channelled into a sump and then flowed via a flow meter into a drain). Water productivity was calculated as the ratio of DM production to water inputs (Meyer 2005). Soil water content (SWC) was measured every three months (at 100 mm intervals to 600 mm and at 200 mm intervals thereafter) to a depth of 2.5 m using a neutron probe.

Climatic data
An automated weather station located within the experimental area collected weather data and was used to determine potential evapotranspiration (Allen et al. 1998).

Statistical analysis
The experimental design was a randomised complete block with four replicates. Forage yield, water-use, nutritive characteristics and water productivity data were compared using analysis of variance. All statistical analyses were performed using Genstat 10 (Payne et al. 2007).

Results
Forage yields in Year 1 (2009/10) ranged from 5.0 t DM/ha in the treatment receiving a single spring irrigation (D 1) to an average of 15.1 t DM/ha in the three treatments which were fully irrigated (Figure 1a). Yields in Year 2 (2010/11) ranged from 12.5 to 14.1 t DM/ha with only the treatments that were not irrigated in 2010/11 yielding less than the other treatments (Figure 1b). High rainfall in spring 2010 meant that a late spring harvest was skipped as the site was too wet to harvest, resulting in lower than expected yields. Yields in Year 3 ranged from 5.2 t DM/ha in the non-irrigated treatment (D 2&3) to over 15 t DM/ha in the 2 treatments irrigated throughout the year (Figure 1c). The forage yields of the treatments that were not irrigated after either mid-November (D SuA 2&3) or mid-January (D A 1,2&3) were intermediate.

Rainfall in Year 1 was close to the long-term average (506 cf. 496 mm) and resulted in an average irrigation water-use in the three fully irrigated treatments of 9.4 ML/ha. Consequently, total water-use (irrigation plus rainfall less runoff plus depletion of soil water) in 2009/10 ranged from 8.0 ML/ha in D 1 to an average of 15.1 ML/ha in the three fully irrigated treatments (Figure 1d). Rainfall in Year 2 totalled 861 mm and included the highest irrigation-season (mid-August – mid-May) rainfall on record (766 mm); this resulted in the highest irrigation water-use being 4.1 ML/ha. Total water-use in Year 2 ranged from 10.5 ML/ha for D 2&3 to 12.7 ML/ha for the Full irrigation treatment (Figure 1e). Water-use in the treatments that were not irrigated after either mid-November (D SuA 2&3) or mid-January (D A 1,2&3) were intermediate. Rainfall in Year 3 slightly exceeded the long-term average (553 cf. 496mm) and resulted in irrigation water-use in the Full treatment of 7.3 ML/ha. Total water-use in Year 3 ranged from 5.9 ML/ha in D 2&3 to 12.9 ML/ha for the Full irrigation treatment (Figure 1f).

The SWC declined in the treatments that were not irrigated for the whole growing season in both Years 1 and 2. In Year 3, however, 156 mm of rain in early autumn necessitated only a single further irrigation for that year and meant that treatments differences in changes in SWC were small (Figure 1f). This extensive drying of the soil profile during non irrigated periods is likely to increase irrigation water-use when irrigation resumes. This can be seen to some extent in the rewetting of the profile of treatment D 1 in Year 2.

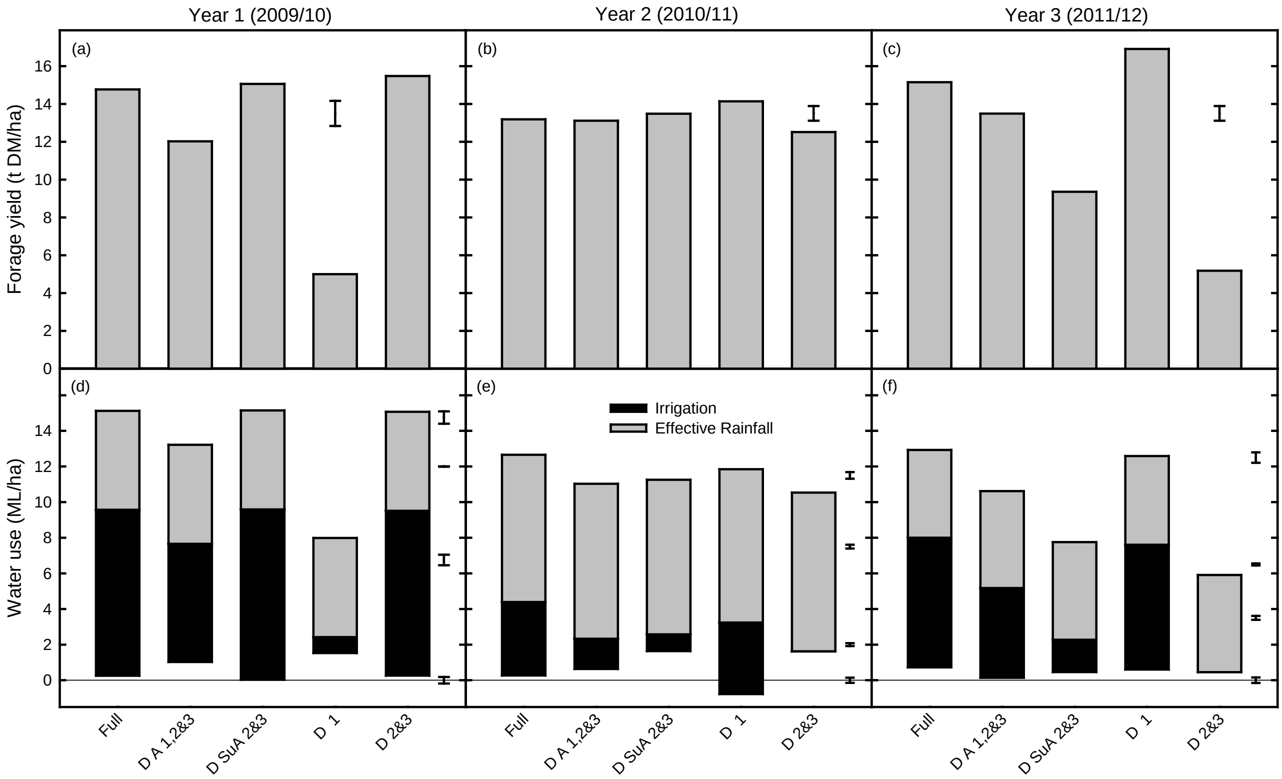

Figure 1. Annual forage yield (a, b and c) and water intake (d, e and f) over three years. Water use comprised changes in soil water content (SWC) (to 2.5 m depth), irrigation and effective rainfall (rainfall less runoff from rainfall). Changes in SWC are indicated by the offsets at the bottom of each column where a positive offset meant a decrease in SWC while a negative offset meant an increase in SWC. The error bars are the between treatment LSD (P=0.05). For water intake the error bars (from the bottom) are for; change in SWC, irrigation, effective rainfall and total water intake.

The soil water profile on 24 February 2012 showed that water-use in the treatments fully irrigated in Year 3 (Full and D 1) was predominantly from the top 1.2 m of the profile (Figure 2). In the treatment that was not irrigated for two years (D 2&3) there was substantial water movement at 2.4 m and a profile soil water deficit to 2.5 m of 360 mm. The profile soil water deficit in the treatments not irrigated after either mid-November or mid-January were intermediate (315 mm in D SuA 2&3 and 225 mm in D A 1,2&3).

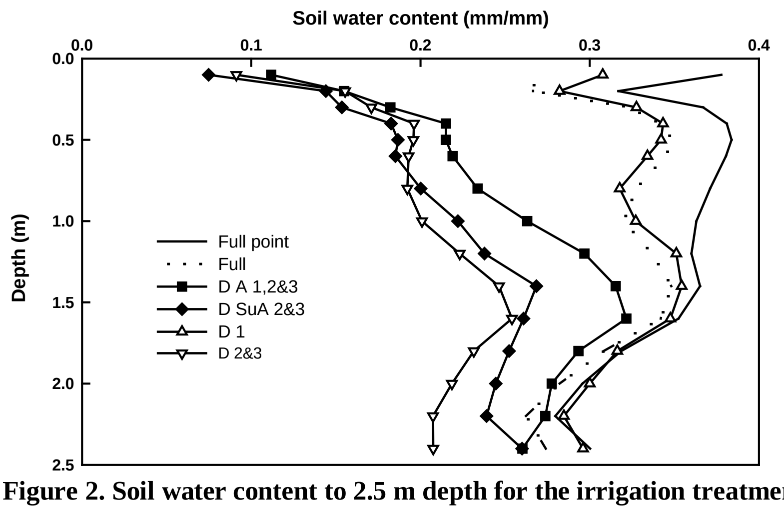

Figure 2. Soil water content to 2.5 m depth for the irrigation treatments on 24 February 2012 (immediately prior to 156 mm of rain). The "full point" corresponds to field capacity.

Irrigation water productivity (WP) (kg DM/ha/mm) varied substantially between treatments and years, and tended to be highest when irrigation water-use was lowest, either due to high rainfall or from being only partially irrigated (Table 1). Total WP in Years 1 and 3 was lowest in the non irrigated treatments while in Year 2 treatment differences were small due to the small range in both yield and water-use

Table 1. Irrigation and total water productivities (kg DM/ha/mm) for five irrigation treatments over 3 years. Total water-use was defined as irrigation plus rainfall less runoff plus depletion of soil water.

	Full	D A 1,2&3	D SuA 2&3	D 1	D 2&3	LSD (P=0.05)
			Year 1 (20009/10)			
Irrigation	16	18	16	57	17	1.8
Total	10	9	10	6	10	0.5
			Year 2 (2010/11)			
Irrigation	32	77	144	35		4.4
Total	10	12	12	12	12	0.8
			Year 3 (2011/12)			
Irrigation	21	23	52	24		2.7
Total	12	13	12	13	9	1.0

Conclusion

Rainfall in Years 1 and 3 was close to average and resulted in large treatment differences in both irrigation water-use and DM production. Record irrigation-season rainfall in Year 2 resulted in a small range in both total water-use (a 4.1 ML/ha lower irrigation water in the non-irrigated treatment corresponded to a 1.5 ML/ha greater reduction in SWC) and forage yield. This close relationship between forage yield and total water-use suggests that provided swards are well watered until at least late spring (all treatments except D 1 in Year 1 and D 2&3 in Year 3), the time at which the last irrigation occurs is likely to have little impact upon total WP. In contrast, the irrigation WP is likely to be higher the earlier that the last irrigation of the season occurs. This suggests that in years of limited availability of irrigation water, total lucerne production is likely to be higher if the available irrigation water is applied across a large area for a limited time (i.e. fully irrigating until a harvest in late spring or summer) than from fully irrigating a smaller area for the entire irrigation season.

This argument ignores any potential carryover effects into the next year. For instance, the non or partial irrigation of some treatments resulted in a reduction in their SWC throughout the irrigation season; in subsequent years this is likely to increase irrigation water-use and hence reduce irrigation WP. Furthermore, there are potential consequences of these irrigation strategies on plant persistence. The results from the next two years of the experiment, including Year 5 in which all treatments will be fully irrigated, will therefore need to be considered before any robust conclusions can be drawn about the effect of intermittent irrigation of lucerne on its water-use, production and persistence.

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