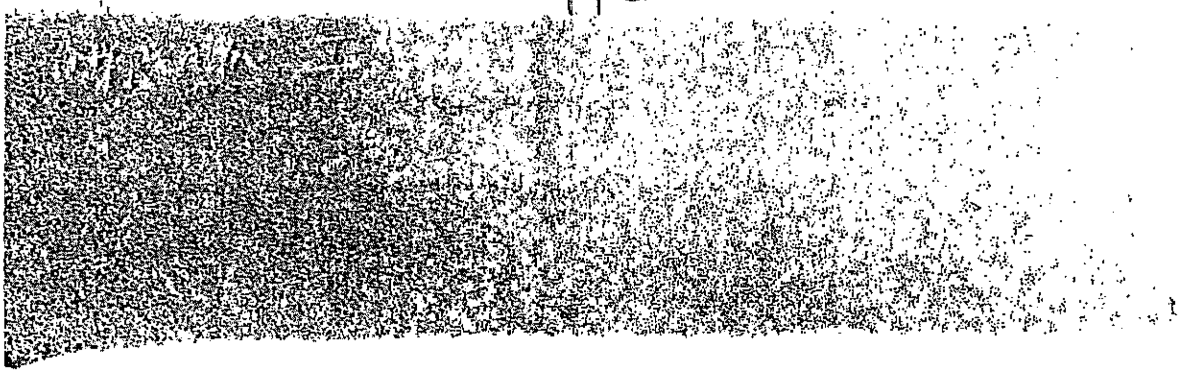
Appendix 1



Using limited irrigation water – crops or pasture?

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Abstract

The irrigation of perennial pasture and the growing of dryland summer forage crops are two common methods of increasing the supply of and nutritional value of home grown forage on dairy farms in south west Victoria. In recent years the amount and reliability of supply of irrigation water to dairy farmers in the region has decreased through drought and increased regulation. Over the last 8 years a series of studies have been conducted to investigate the most efficient use of unreliable irrigation water supplies. Perennial pasture was found to be particularly sensitive in terms of reduced productivity and water use efficiency (WUE) to poor irrigation practices. However, under good management and reliable water supply it is still likely to be the easiest and most economically efficient irrigation system Irrigated summer forage crops were found to have a higher WUE, but responses were variable due to year to year seasonal differences. These crops were found to be more tolerant of poor irrigation management and were able to take advantage of reduced amounts of irrigation water and one off irrigations.

Keywords: brassicas, forage crops, irrigated pasture, irrigation, water use efficiency.

Introduction

The climate of south west Victoria is characterised by winter dominant rainfall coupled with high summer temperatures and evaporation rates, resulting in low summer pasture growth rates and a marked decline in the nutritional value of pasture. This in turn leads to a rapid decline in milk production, unless supplements (e g. grain) or other forages are fed. Two of the most common methods of increasing the supply of home grown forage are growing of summer forage crops and irrigation of perennial pasture.

Some 18% of dairy farms in the south west have licences to irrigate land through private diversions from rivers, dams and groundwater extraction (Ward *et al.* 1998). In recent years the amount of water available for irrigation and the reliability of supply has decreased through a combination of prolonged drought and legislative changes. The implementation of stream flow management plans has resulted in week to week variation in water availability, including total irrigation bans, in order to meet minimum river flow requirements In other districts, the implementation of groundwater supply protection areas may lead to reductions in licence volumes

Traditionally dairy farmers in the region have used their water allocation to irrigate perennial ryegrass (*Lolium perenne* L.) – white clover (*Trifolium repens* L) pastures. Questions have been raised as to whether this is the most efficient and profitable use of this increasingly expensive and unreliable resource. Research in other regions suggests that summer forage crops may give better responses to applied water and be more tolerant of poor irrigation scheduling (Pritchard 1987; Armstrong *et al.* 2000; Eckard *et al.* 2001).

Trial Program

Perennial pasture

Initial trials determined ideal irrigation startup times in spring and optimum irrigation schedules for the region including amounts of water required and application interval for perennial ryegrass (*Lolium perenne* L.) – white clover (*Trifolium repens* L.) pasture (Ward 1999) Losses in herbage production and reductions in water use efficiency (WUE; t DM/ha ML of applied irrigation water) due to sub-optimal irrigation practices were studied. These included late start up times in the spring, excessively long application intervals (an excessively long irrigation interval treatment was imposed by delaying the next irrigation for 3-4 days after a 30 cm depth tensiometer reading exceeded 30 kPa (Ward 1999)) and applying less water than plants required. (Ward *et al* 1998).

Summer forage crops

Subsequent trials investigated the responses to and WUE of irrigating a range of summer forage crops. The effectiveness of restricted irrigation regimes including a range of suboptimal water application rates and irrigating only at certain times during the crop's growth were investigated One set of trials (Jacobs *et al.* 2004), compared the responses of turnips (*Brassica rapa* L. cv Vollenda) to weekly irrigations of 100%, 75%, 50% and 25% of estimated crop water requirements relative to a non-irrigated control Other irrigation treatments imposed were a single application of 50 mm of irrigation water at either 0-6, 6-8, 8-10 or 10-12 weeks after the crop was sown. In a second trial (Jacobs *et al.* 2006), responses from regrowth summer forage crops, turnip-rape (*Brassica campestris* L. x *Brassica napus* L. cv Hunter), radish (a complex hybrid of *Raphanus sativus* L with

Table 1 Effect of delayed irrigation and under irrigation on the pasture DM production (t DM/ha) and irrigation water use efficiency (t DM/ha ML) for Jan – Mar 1998 and on the herbage nutritive value of samples collected on 26 February.

Treatment	Pasture DM production (t DM/ha)	Water use efficiency (t DM/ha.ML)	Metabolisable energy (MJ/kg DM)	Crude protein (% DM)
Control	3.56	1.04	11.4	27.3
Delayed irrigation	2 0·	0 57	11 4	26.0
Under irrigated	2 03	0.82	11 2	26 0
LSD (P=0.05)	0.485	0.151	0.30	1 13

intogression from *Raphanus maritimus* L. and *Brassica oleracea* L. cv Graza) and millet (*Echinochloa utilis* Ohwi & Yabuno cv. Shirohie) were compared. Irrigation treatments were a non-irrigated control, weekly irrigation to 100% and 50% of estimated perennial pasture water requirements and applications every second week of 50% of estimated pasture requirements for a week. Detailed climatic information for these two trials are listed in Jacobs *et al.* (2004) and Jacobs *et al.* (2006) respectively.

Results and Discussion

Perennial pasture

The results of the pasture trials confirm that the WUE of irrigation water applied to perennial ryegrass-white clover in south west Victoria under good commercial management is in the order of 1.0 t DM/ha.ML (Table 1) (Ward *et al.* 1998). This value has been used for feed planning in southern Victoria (Mount pers. comm.) for a number of years and is in line with northern Victorian findings of 0.7-1.3 t DM/ha.ML for irrigated perennial pasture (Armstrong *et al* 2000).

Perennial ryegrass-white clover pasture was very sensitive to poor irrigation scheduling and practices. Commencing irrigation 10 and 20 days after the optimum time was found to reduce herbage accumulation by 35% and 60% compared to an optimum control for the period mid December to early February (Ward *et al* 1998). Where only 70% of estimated water requirement was applied to the pasture each week, pasture DM production for the season fell by 43% and WUE fell from 1 04 to 0.82 t DM/ha.ML compared to the treatment receiving 100% of estimated requirements (Table 1) Despite 100% of the estimated water requirement being applied after delaying the next irrigation by 3-4 days, pasture DM production for the summer declined by 46% and WUE fell to 0.57 t DM/ha.ML (Table 1).

Summer forage crops

The irrigation of turnips produced variable results depending on the season. In year 1, DM production from the fully irrigated treatment was almost double that of the dryland, while in year 2, no significant responses (P>0 05) to irrigation were found (Table 2). This difference is thought to be a result of large differences in summer temperatures experienced between the two years, (illustrated by the differences in irrigation requirements, Table 3), and it is indicative of the variable ability of such crops to respond to variations in climatic conditions. Despite the WUE figures being variable, they are in line with the 1.5-2.2 t DM/ha ML responses found for turnips in Tasmania by Eckard *et al.* (2001). Importantly, they are greater than the WUE figures obtained for perennial

Table 2 Effect on total DM production (t DM/ha) and irrigation water use efficiency (t DM/ha.ML) over 2 years of Vollenda turnip crops irrigated weekly at a range of rates between 25% and 100% of estimated requirements and for one-off 50 mm irrigations at a range of times after sowing compared to a dryland control treatment

Treatment	Year 1		Year 2	
	Total DM production (t DM/ha)	Water use efficiency (t DM/ha.ML)	Total DM production (t DM/ha)	Water use efficiency (t DM/ha ML)
Dryland	4.94	-	9 36	-
100% of req	10.34	1.48	10.30	0.53
75% of req	8 61	1.29	9.91	0.46
50% of req.	8 40	1.81	10.39	1.15
25% of req.	5.81	0.90	9.99	1.55
0-6 weeks	5.40	1.14	8.93	-0.88
6-8 weeks	5.10	0.32	8.97	-0.66
8-10 weeks	6.44	2.99	9 67	0.97
10-12 weeks	6.12	2 36	9.25	0 08
LSD (P=0.05)	1 051	1.778	1.379	1.490

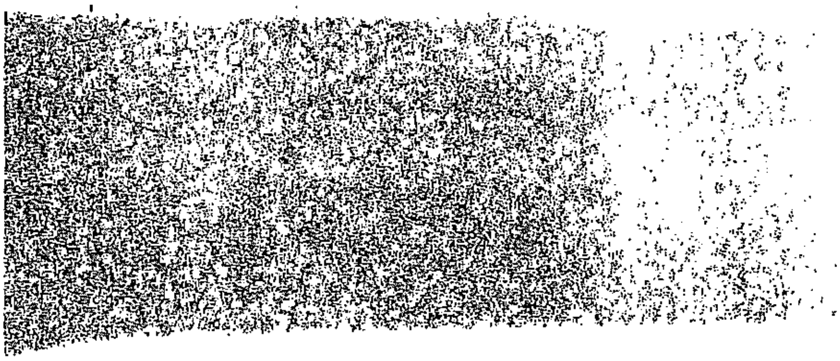

Table 3 Irrigation water applied (ML/ha) and the cost of herbage grown ($/t DM) over two years of Vollenda turnip crops irrigated weekly at a range of rates between 25% and 100% of estimated requirements and for once off 50 mm irrigations at a range of times after sowing compared to a dryland control treatment

Irrigation Treatment	Dryland	100%	75%	50%	25%	8-10 weeks	10-12 weeks
Year 1							
Water applied (ML/ha)	-	3.80	2 85	1.90	0.95	0.5	0.5
Cost($/t DM)	166	116	128	120	158	135	142
Year 2							
Water applied (ML/ha)	-	2.10	1.58	1.05	0.53	0.5	0.5
Cost($/t DM)	88	100	99	89	88	90	94

pasture (Table 1), indicating that turnips are a more efficient user of irrigation water. The DM production responses and comparatively high WUE figures for the single 50 mm irrigation applications at weeks 8-10 and 10-12 in year 1 also suggest that turnips can be effective utilisers of one-off irrigation applications.

Jacobs *et al* (2004) provided costs of growing these crops under the different irrigation regimes (Table 3), and, whilst year to year data varies, it would appear that under good growing conditions, the costs are comparable with irrigated perennial pasture ($78-112/t DM/ha) (Robaina 1999).

For the regrowth forage crops (Jacobs *et al.* 2006), the 100% irrigation treatment produced significantly ($P<0.05$) higher DM yields than dryland crops in both years for all crops (Table 4). As with turnips, the WUE of applied irrigation water varied considerably between years and also between crops. Irrigation WUE's in the range of 1 3-1.8 t DM/ha ML were recorded for the brassicas in year 2, while the millet crop recorded higher WUE values at the restricted irrigation treatments. High WUE for millet is consistent with it being a C4 plant (Begg and Turner 1976), but comes at the expense of herbage nutritive value

Practical implications

Irrigation of perennial pasture is the easiest and often the most economically efficient system of using irrigation water for summer forage production on farm. However, our work has shown that it is very sensitive to poor irrigation scheduling and practices. There are large penalties in terms of both reduced herbage DM production and WUE whenever pasture plants go into water stress through:

- Late start up in spring,
- Insufficient water being applied to fully meet plant requirements,
- Intervals between irrigations being too long

Under volume restrictions, our work indicates that it is more efficient and productive to reduce the area of pasture irrigated and apply the plants' full water requirements. Under-irrigating pasture results in a greater decline in DM production and WUE compared to the water saved.

Table 4 Effect on crop DM production (t DM/ha) and irrigation WUE (t DM/ha.ML) over 2 years of turnip-rape, radish and millet crops irrigated weekly at 100% and 50% of estimated pasture requirements and fortnightly at 50% compared to a dryland treatment

Irrigation Treatment	Turnip-rape				Radish				Millet			
	Year 1		Year 2		Year 1		Year 2		Year 1		Year 2	
	DM Prodn	WUE	DM Prodn	WUE	DM Prodn	WUE	DM Prodn	WUE	DM Prodn	WUE	DM Prodn	WUE
Dryland	7.81	-	8.42	-	7.13	-	5.61 (1.72)[1]	-	11.95	-	8.04	-
100%	12.59	1.18 (0.346)	14.32	1 55	12 32	1.31 (0.350)	10.82 (2.38)	1.43 (0.266)	14.89	0.77 (0.332)	13 76	1 50
50%	10.20	1.18 (0.346)	11.93	1.84	10.41	1.55 (0.357)	8.65 (2.16)	1 33 (0.259)	14.61	1.34 (0.351)	13.51	2.87
50% fortnightly	7.81	-0.29 (0.284)	10.13	1.78	8.01	0.53 (0 323)	7 42 (2.01)	1.36 (0.261)	13.22	0.33 (0.315)	11 17	3.27
LSD(P=0.05)	1.708	(0.42)	2.114	2.193	0.895	(0.026)	(0.199)	(0.079)	1.671	(0.072)	1.655	0.962

[1]Values in parentheses are transformed means with LSD referring to transformed data.

Our work has also confirmed that irrigated summer forage crops often have a higher WUE than perennial pasture but this advantage is not expressed every year. Where the full cost of growing an irrigated summer forage crop (including establishment costs, pasture forgone resowing the pasture) is included, then the cost of the herbage grown will in some years be greater than the cost of an efficiently managed irrigated pasture system. Where, however, some of these costs can be allocated as part of a normal pasture renovation program, the economics of irrigated forage crops become more attractive.

In our experience, the irrigation of summer forage crops offers the best potential to productively utilise unreliable irrigation water supplies. Such crops are considerably more tolerant of missed irrigations than perennial pasture. Forage crops provide good responses in DM yield and WUE to one-off irrigation in the mid to later phases of their growth cycle. The forage crops are usually only irrigated for a shorter time period over summer. They will grow on conserved soil moisture for the initial crop establishment period, allowing irrigation to commence during the rapid growth phase of the crop. Our results also indicate that regular partial irrigations at around 50% of estimated perennial pasture requirements will often give the best WUE for limited irrigation water.

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