Effect of irrigation strategies on dry matter yields and water use efficiency of a range of forage species

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Abstract

A study determined the effect of different irrigation strategies on dry matter (DM) yield, water use efficiency (WUE) and marginal water use efficiency (MWUE) of perennial ryegrass (Matrix), millet and two forage brassicas (Hunter and PG545). Irrigation treatments were dryland control (A), irrigated to 100% (B) and 50% (C) of estimated requirements each week and 50% (D) of estimated requirements every second week.. At each irrigation level, nitrogen (N) was applied at either 50 or 100 kg N/ha after each grazing. Irrigation treatments were imposed from early November until late March.

Where species were fully irrigated (B) there were higher ($P<0.05$) DM yields than for the dryland treatment (A). For the ryegrass and two brassica species there were also higher ($P<0.05$) DM yields when irrigated at 50% of requirements on a weekly basis (C). Application of N at the higher rate also led to higher ($P<0.05$) DM yields. Total WUE was higher ($P<0.05$) for the dryland treatment (A) than for the fully irrigated treatment (B) for all forages. For dryland treatments (A), millet had a higher ($P<0.05$) WUE than all other species. Application of N at the higher rate also improved ($P<0.05$) WUE for all species. The MWUE were similar for all irrigation treatments across all forages.

The forages used in this study all responded to irrigation, with the degree of response dependent upon volume of water applied. Further work is required to define the optimal irrigation strategies to maximise DM yield and WUE.

Media summary

A range of irrigation strategies were used to increase the DM production of ryegrass, millet and brassica forage crops

Key Words

Ryegrass, millet, brassica

Introduction

In south western Victoria approximately 18% of dairy farmers (450) have licences to irrigate land through surface diversions from rivers, dams or ground water extraction. Through the imposition of streamflow management plans and groundwater protection areas, there will be a reduction in both the quantity and reliability of irrigation water supply in the region. There is a need to develop strategies to enable farmers to maximise water use efficiency (WUE) in a sustainable manner and in turn minimise the potential production effects of any future reduction in the amount and reliability of water available for irrigation.

Traditionally dairy farmers in south west Victoria have irrigated perennial pastures (ryegrass / white clover). Such pastures are deemed to be relatively poor utilisers of water with WUE's under commercial conditions of about 1 t DM/ML water (Armstrong *et al* 2000). Ward *et al* (1998) showed that perennial ryegrass white clover pastures become dormant after short periods of water stress, and are then slow to recover productive potential despite adequate watering. Summer forage crops such as turnips are known to use water more efficiently than pasture and recent studies undertaken in south west Victoria have shown that WUE's about 1.5 t DM/ML are achievable (Jacobs *et al* 2003). Studies in the Northern

Irrigation region of Victoria have indicated that C4 crops such as Maize have the potential to produce 3 - 3.5 tDM/ML (Pritchard 1987).

This study determines the effect of irrigating a range of forages with varying amounts of water with differing N application rates on subsequent DM yields and WUE.

Methods

The study was conducted on a commercial dairy farm (38^o 33'S, 142^o 63'E) in south western Victoria located in the Merri river irrigation area close to Warrnambool. The soil type was a light clay of alluvial origins with initial soil tests at the site indicating soil pH_{H20} of 6.0, Olsen P of 59 mg/kg, Skene K of 225 mg/kg and CPC S of 24 mg/kg.

Site establishment commenced with the existing pasture being sprayed out on 25 September with Roundup Max @ 3 L/ha (540 g/L glyphosate), Dicamba @ 500 ml/ha (500 g/L dicamba) and LeMat @ 100 ml/ha (290 g/L omethoate). Seven days after spraying the area was cultivated using a chisel plough followed by power harrowing. Perennial ryegrass (*Lolium perenne cv* Matrix) plots were sown (20 kg/ha plus 3 kg/ha white clover (*Trifolium repens cv* Sustain) on October 7 2002. On October 17, both forage brassica crops, Hunter (*Brassica campestris* x *Brassica napus*) and PG545 were sown (5 kg/ha and 8 kg/ha respectively). On November 13, Millet (*Echinochloa utilis cv* Shirohie) plots were sown at a rate of 20 kg/ha. All treatments were sown with 100 kg/ha single super (8.8 kg P, 11 kg S) and rolled, with 100 kg/ha Muriate of Potash (50 kg K) being applied two weeks after sowing.

A strip plot design was utilised with species randomly allocated to strips, replicated twice, and irrigation treatments randomly applied to plots within strips, two replicates per strip. Each plot was further split into 2 subplots, each half being being randomly allocated to either 50 or 100 kg N/ha applied as urea after establishment and then after each grazing.

Irrigation treatments were dryland control (A), irrigated to 100% (B) and 50% (C) of estimated requirements each week and 50% (D) of estimated requirements every second week.. Irrigation water requirements for treatment B were estimated using a 'Class A' evaporation pan located at the trial site. Water requirement was based on evaporation from the pan minus effective rainfall (rainfall greater than 3 mm in a rain event) and multiplied by a crop factor of 0.8. Irrigation water requirements for treatments C and D were calculated as a proportion of the requirements for B. Total water applied for treatments B, C and D were 394, 197 and 104 mm respectively.

Irrigation water was applied via a pressurised spray system (Irrifrance, Bosch Engineering) with sprinklers located on a 12 m x 12 m grid system (corner of each plot) with each sprinkler covering a 90^o arc ensuring a high distribution uniformity. Irrigation of plots was only undertaken during zero to low wind conditions.

Matrix plots were grazed when the most advanced treatments attained a pre grazing mass of 2600 - 2800 kg DM/ha. Dry matter yield (kg DM/ha) was estimated by measuring pre- and post-grazing pasture mass with a calibrated rising plate meter (Earle and McGowan 1979). For all other forages, on the day prior to grazing six quadrats (each of 1.0 m^2) were harvested per sub plot by cutting individual plants at a height of 5 cm above ground level. The harvested herbage was collected, each quadrat weighed individually and sampled on a plot basis. Samples were thoroughly mixed and a sub sample taken to determine DM yield by drying at 100^oC for 24 h.

Water use efficiency was calculated as the amount of crop grown (kg DM/ha) per mm of water applied, with water applied defined as effective rainfall plus irrigation. Marginal WUE (kg DM/ha/mm irrigation water) was calculated as the additional DM yield produced (DM yield minus control DM yield (A)) from applied irrigation water.

Statistical analysis was undertaken using analysis of variance (ANOVA) (GenStat Committee 2000) to compare species, level of irrigation and the interaction between these parameters, with significance declared if P<0.05.

Results

Where forages were fully irrigated (B) there were higher (P<0.05) DM yields than for the dryland treatment (A) (Table 1). For the ryegrass and two brassica species there were also higher (P<0.05) DM yields when they were irrigated at 50% or requirements on a weekly basis (C). In addition, for these three crops weekly irrigation resulted in higher (P<0.05) DM yields than treatment D. Millet resulted in higher (P<0.05) DM yields than other species at all irrigation treatments apart from B. Application of N at the higher rate produced higher (P<0.05) DM yields (data not presented).

Total WUE was higher (P<0.05) for the dryland treatment (A) than for the fully irrigated treatment (B) for all forages (Table 2). For treatments A, C and D, millet had a higher (P<0.05) WUE than all other species. Both the ryegrass and millet had higher (P<0.05) WUE when fully irrigated (B) than either of the brassica forages. Application of N at the higher rate also improved (P<0.05) WUE (data not presented). The MWUE were similar for all irrigation treatments across all forages, ranging from 6 to 20 kg DM/ha/mm.

Table 1. Effect of irrigation (dryland (A), fully irrigated weekly (B), 50% of irrigation weekly (C), 50% of irrigation every other week (D)) from early November to late March on the dry matter yield (t DM/ha) of ryegrass (Matrix), millet (Shirohie) and two forage brassicas (Hunter and PG545)

	A	B	C	D
Matrix	5.4	12.7	9.4	7.1
Millet	11.5	14.4	14.1	12.7
Hunter	7.7	12.4	10.2	8.3
PG545	7.1	12.3	10.4	8.0

l.s.d = 2.41 (P=0.05)

Table 2. Effect of irrigation (dryland (A), fully irrigated weekly (B), 50% of irrigation weekly (C), 50% of irrigation every other week (D)) from early November to late March on the water use efficiency (kg DM/ha/mm effective rainfall and irrigation) ryegrass (Matrix), millet (Shirohie) and two forage brassicas (Hunter and PG545)

	A	B	C	D
Matrix	30.2	22.2	25.0	25.1

Millet	87.8	28.1	44.0	54.3
Hunter	37.5	20.0	25.0	26.2
PG545	39.7	21.5	27.7	28.3

l.s.d = 0.78 (P=0.05)

Discussion and Conclusions

Previous studies in similar environments have all shown positive responses to the irrigation of perennial ryegrass pastures (Ward *et al* 1998), brassica crops (Eckard *et al* 2001, Jacobs *et al* 2003, Nielsen *et al* 2000) and C4 species (Eckard *et al* 2001). Where perennial ryegrass pastures were irrigated on a weekly schedule to field capacity (Ward *et al* 1998), WUE values of 8–23 kg DM/ha/mm were observed, values generally lower then observed in this study. Overall in this study, where perennial ryegrass (Matrix) was irrigated weekly (B and C), the DM yields increases were almost double that of the dryland treatment. The work of Eckard *et al* (2001) questioned the value of irrigating perennial ryegrass pastures compared to either brassica crops or C4 species such as millet. Eckard *et al* (2001) in a study undertaken in Tasmania, indicated a modest increase in DM yield of perennial ryegrass to irrigation (0.2 tDM/ha) compared to millet (1.5 tDM/ha) and suggested that the low response to irrigation by perennial ryegrass may be due to adequate rainfall to meet growth requirements.

Studies by Eckard *et al* (2001) and Neilsen *et al* (2000) compared a range of brassica crops and stated that a single grazed crop such as turnips produced more DM and had higher WUE than multi grazed crops, similar to those used in this study. The value of using multi grazed crops is in providing feed throughout the summer as opposed to a once off feed surplus as provided by crops such as turnips. Results from this study indicate that both brassica species used, when irrigated weekly gave rise to DM yield increases of between 40 – 80% higher than the dryland treatment. These values are close to those observed for turnips watered weekly in the study of Jacobs *et al* (2003). Correspondingly, the marginal WUE values for both Hunter and Radish are close to those found by Jacobs *et al* (2003) for turnips indicating that in south west Victoria, brassica crops in general respond to irrigation in a similar manner and therefore the choice of species will be dictated by the feed pattern required.

The high apparent WUE of millet in comparison to other species is of interest. During this trial the use of stored water within the soil profile was not measured and it is possible that millet has either a greater ability to utilise this stored water or is a more efficient user of available water over the summer period. These aspects warrant further investigation in the future. It is also notable that millet has higher WUE under the restricted irrigation strategy (D). The data would suggest that where irrigation water supply may be restricted and unreliable, millet may become a preferred option.

In conclusion, the results show that the greatest potential for DM production and WUE under dryland conditions was with millet, although other species also performed well given the dry hot conditions observed during this period. The data also indicates that there is potential to irrigate the range of species used in this study in terms of providing additional DM production of high nutritional value to help meet the feed requirements of lactating dairy cows. Further work is required in subsequent years to determine the year to year variation from irrigation of such species.

References

Armstrong DP Knee JE Doyle PT Pritchard KE and Gyles OA (2000) Water sue efficiency on irrigated dairy farms in northern Victoria and southern New South Wales. Australian Journal of Experimental Agriculture 40, 643-654.

Earle DF and McGowan AA (1979). Evaluation and calibration of an automated rising plate meter for estimating dry matter yield of pasture. Australian Journal of Experimental Agriculture. **19**, 337-43.

Eckard RJ Salardini AA Hannah M and Franks DR (2001) The yield, quality and irrigation response of summer forage crops suitable for a dairy pasture renovation program in north western Tasmania. Australian Journal of Experimental Agriculture 41, 37-44

GenStat (2000) GenStat for Windows. Release 4.2. Fifth Edition. VSN International Ltd. Oxford.

Jacobs JL Ward GN and Kearney G (2004) Effects of irrigation strategies and nitrogen fertiliser on turnip dry matter yield, water use efficiency, nutritive characteristics and mineral content in western Victoria. Australian Journal of Experimental Agriculture 44, in press

Neilsen JE Rowe BA and Lane PA (2000) Water use efficiency of four irrigated brassica forage crops. In 'Proceedings of the Irrigation Association of Australia Conference'. (Ed. GJ Connellan) pp136-139. (Irrigation Association of Australia: Melbourne).

Pritchard KE (1987) Potential productivity of irrigated maize in northern Victoria. In 'Proceedings of the 4th Australian Agronomy Conference'. (Ed TG Reeves) p.314. (The Australian Society of Agronomy: Australia)

Ward G Burch S Jacobs J Ryan M McKenzie F and Rigby S (1998) Effects of sub-optimal irrigation practices dairy pasture production in south west Victoria In 'Proceedings of the 9th Agronomy Conference', (Ed DL Michalk and JE Pratley) pp254-257. (Charles Sturt University, Wagga Wagga, NSW)