Effects of irrigation on yields and water use efficiencies of forages

Joe Jacobs and Graeme Ward
Department of Primary Industries, 78 Henna Street, Warrnambool, Vic 3280Australia
joe.jacobs@dpi.vic.gov.au

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 forages were irrigated weekly (B and C) there were higher ($P<0.05$) DM yields than for the dryland treatment (A). Application of N at the higher rate led to higher ($P<0.05$) DM yields for the perennial ryegrass and PG545. Total WUE was higher ($P<0.05$) for the dryland treatment (A) than for the fully irrigated treatment (B) for all forages. Application of N at the higher rate also improved ($P<0.05$) WUE for perennial ryegrass and PG545.

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

Additional key words: Ryegrass, millet, brassica

Introduction

In south west 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 negative 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 of 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 t DM/ML (Pritchard, 1987).

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

Methods

The study was conducted on a commercial dairy farm (38 ° 33'S, 142 ° 63'E) in south west Victoria. The farm is located in the Merri river irrigation area close to Warrnambool. The soil type was a light clay of alluvial origin with initial soil tests (0-10 cm) 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 2002 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. 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 superphosphate (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.

Within a strip plot design treatments were replicated four times in 12 m x 12 m plots. 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. Given the differing grazing regimes imposed (Matrix 5 grazings; Hunter and PG545 3 grazings; millet 2 grazings), total N application varied across species.

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° arc ensuring a high distribution uniformity. Irrigation of plots was only undertaken during zero to low wind conditions.

Matrix ryegrass plots were grazed when the most advanced treatments attained a pre-grazing mass of 2600 - 2800 kg DM/ha. Ryegrass DM 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 brassicas and millet, 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 content by drying at 100 °C for 24 h.

Water use efficiency was calculated as the amount of crop harvested (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 level of irrigation and effect of N within species, with significance declared if $P<0.05$.

Results

Where forages were irrigated weekly (B and C), there were higher ($P<0.05$) DM yields than for the dryland treatment (A) (Table 1). For Matrix, irrigating every other week (D) also led to a higher (P<0.05) DM yield than the control. For Matrix, Hunter and PG545, weekly irrigation resulted in higher (P<0.05) DM yields than where irrigation occurred every other week (D). For both Matrix and PG545, application of N at the higher rate resulted in an increase (P<0.05) in DM yield.

Total WUE for all forages was higher (P<0.05) for the dryland treatment (A) than all irrigated treatments (Table 2). For Hunter, PG545 and millet, the WUE under full irrigation (B) was lower than the other irrigation treatments (C and D). Application of N at the higher rate resulted in a higher (P<0.05) WUE for Matrix and PG545.

Table 1. Effect of irrigation (dryland (A), fully irrigated weekly (B), 50 % of irrigation weekly (C), 50 % of irrigation every other week (D)) and level of N application (50 kg N/ha after every grazing (N0), 100 kg N/ha after every grazing (N1)) 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	N0	N1	l.s.d. Irrig	l.s.d. N
Matrix	5.41	12.71	9.41	7.11	8.25	9.08	1.118	0.551
Millet	11.45	14.39	14.11	12.72	12.81	13.53	1.671	0.965
Hunter	7.69	12.43	10.24	8.28	9.08	10.24	1.528	1.160
PG545	7.13	12.32	10.41	8.01	8.60	10.34	0.895	0.998

Table 2. Effect of irrigation (dryland (A), fully irrigated weekly (B), 50 % of irrigation weekly (C), 50% of irrigation every other week (D)) and level of N application (50 kg N/ha after every grazing (N0), 100 kg N/ha after every grazing (N1)) 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	N0	N1	l.s.d. Irrig	l.s.d. N
Matrix	30.2	22.2	25.0	25.1	24.7	26.6	5.08	1.52
Millet	87.8	28.1	44.0	54.3	51.5	55.7	10.63	4.71
Hunter	37.5	20.0	25.1	26.2	25.5	28.8	3.15	3.22
PG545	39.7	21.5	27.7	28.3	26.8	31.8	3.48	3.53

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.,* 2004, Nielsen *et al.,* 2000) and C4 species (Eckard *et al.,* 2001). Where perennial ryegrass pastures were irrigated weekly to field capacity (Ward *et al.,* 1998), WUE values of 8–23 kg DM/ha/mm were observed; values generally lower than those observed in this study. Overall in this study, where perennial ryegrass (Matrix) was irrigated weekly (B and C), the DM yield 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 with millet (1.5 tDM/ha) and suggested that the low response to irrigation by perennial ryegrass may have been due to adequate rainfall to meet growth requirements. Data from the current study shows higher DM yields for both perennial ryegrass and millet compared to those of Eckard *et al.*, (2001) irrespective of irrigation regime. This may be due to a number of factors including higher initial soil fertility, higher N application rates and warmer summer temperatures.

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, 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.,* (2004). Correspondingly, the marginal WUE values for both Hunter and PG545 are close to those found by Jacobs *et al.,* (2004) 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 WUE of millet in comparison with other species is of interest. It is postulated that this may be a result of several different factors. It is well established that C4 grasses such as millet have greater transpiration efficiencies (herbage grown per volume of water transpired) than other C3 grasses and crops (Loomis and Connor 1998). In this study, the depletion of water stored in the soil profile over the irrigation period was not measured. Millet may have extracted and utilised more of this stored soil water than the other species. It is also possible that millet, through rapid early leaf growth, was able to form an effective canopy, reducing water losses by direct evaporation from the soil surface, and allowing more of the available water to be used for crop transpiration These aspects warrant further investigation. It is also notable that millet had a high 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 although consideration to nutritive value of resultant crops would also be required.

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 during this period. The data also indicate that there is potential to irrigate the range of species used in this study in terms of providing additional DM to help meet the feed requirements of lactating dairy cows. An additional consideration will be the nutritive value of the feed produced and this fits with other available feeds on dryland dairy farms during the summer period. Further work is required to determine the year-to-year variation from irrigation of such species.

References

Armstrong, D.P., Knee, J.E. Doyle, P.T. Pritchard, K.E. and Gyles, O.A. 2000 Water use efficiency on irrigated dairy farms in northern Victoria and southern New South Wales. *Australian Journal of Experimental Agriculture* 40:643-654.

Earle, D.F. and McGowan, A.A. 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, R.J., Salardini, A.A., Hannah, M. and Franks, D.R. 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, J.L., Ward , G.N. 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* 44:13-26.

Loomis, R.S. and Connor, D.J. 1998. Crop ecology: productivity and management in agricultural systems. *Cambridge University Press,* Cambridge.

Neilsen, J.E., Rowe, B.A.and Lane, P.A. 2000. Water use efficiency of four irrigated brassica forage crops. *Proceedings of the Irrigation Association of Australia Conference.* (Ed. GJ Connellan) pp136-139. (Irrigation Association of Australia: Melbourne).

Pritchard, K.E. 1987. Potential productivity of irrigated maize in northern Victoria *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. *Proceedings of the 9th Agronomy Conference*, (Ed D.L.Michalk,.and J.E. Pratley) pp254-257. (Charles Sturt University, Wagga Wagga, NSW).