Irrigated dairy pasture yield and water use efficiency responses to summer applied nitrogen

F.R. MCKENZIE, J.L. JACOBS and G.N. WARD
Department of Primary Industries, 78 Henna Street, Warrnambool, Vic 3280, Australia
frank.mckenzie@dpi.vic.gov.au

Abstract

Two experiments determined the potential of N fertiliser to maximise the conversion of summer (October to April) irrigation water to pasture dry matter (DM) in southwest Victoria, Australia. DM consumed increased with increasing N (0 to 100 kg N/ha per grazing, and 50 to 200 kg N/ha every second grazing). Applications of 75 to 100 kg N/ha every grazing, and 150 to 200 kg N/ha every second grazing resulted in the highest water use efficiencies (improvements of 25 to 70% in Year 1, 40 to 63% in Year 2). Applications of 25 kg N/ha every grazing and 50 kg N/ha every second grazing led to the highest N response efficiencies (10 to 19 kg DM/kg N). The increases in DM consumed in response to N fertiliser were similar to responses noted for N applied during autumn, winter and spring in similar environments to the current experiments.

Keywords: dry matter, perennial ryegrass, urea, water use efficiency

Introduction

Low summer rainfall in southwest Victoria, Australia, restricts pasture growth and limits milk production. One fifth of dairy farmers in the region have some capacity to irrigate. Irrigated dairy pastures are relatively poor utilisers of water with water use efficiencies (WUE) of about 1 t DM/ml applied water (Ward *et al.* 1998). Using nitrogen (N) fertiliser may increase dry matter (DM) responses for a given amount of water. Data on N response efficiencies from irrigated pasture in southwest Victoria are lacking. Two experiments determined the potential of N fertiliser to maximise the conversion of irrigated water to pasture DM.

Methods

Experiments were conducted during the summers of 2003/04 and 2004/05 on two commercial farms on 4-year-old established dairy pastures. Site 1 (38°28'S, 142°45'E) was under fixed sprinkler irrigation and Site 2 (38°27'S, 142°42'E) under centre pivot irrigation. Perennial ryegrass (*Lolium perenne* L.) dominated (84 to 88% DM) both sites. Soil tests (0 to 10 cm) in October 2003 revealed: 26 and 28 mg/kg P (Olsen method), 120 and 230 mg/kg K (Skene method), 19 and 24 mg/kg S (CPC method) and $pH_{(water)}$ 6.7 and 6.0 for Sites 1 (dark-grey sandy loam soil) and 2 (dark brown-grey loam soil) respectively.

During the irrigation season (mid October 2003 to end of April 2004, Year 1, and November 2004 to end April 2005, Year 2), N fertiliser (urea; 46% N) was applied at: 0, 25, 50, 75 and 100 kg N/ha every grazing, and 50, 100, 150 and 200 kg N/ha every second grazing. These N applications were made to 12 m x 24 m plots, replicated three times in a randomised block design.

Plots and the remaining paddock were communally grazed by the lactating dairy herd on each farm. Irrigation scheduling and volume applied was calculated weekly from soil moisture measurements using neutron probes. Soil fertility, weed and pest control were all based on current 'best management practice' for the soil and climatic conditions at the sites. Grazing rotations were set by the farmers in Year 1, and based on perennial ryegrass reaching the three-leaf stage in Year 2 (Fulkerson & Slack 1994). Three applications of a P, K and S blend (each equivalent to 8 kg P/ha, 27 kg K/ha and 8 kg S/ha) were applied at 6-week intervals to both sites during both summers.

Pasture dry matter (DM) consumed from each treatment plot was measured as the difference between pasture DM before and after grazing using a calibrated rising plate meter (Earle & McGowan 1979). Forty pre- and post-grazing readings were taken from each plot. An analysis of variance (GenStat Committee 2003) was undertaken on DM consumed with significance declared at $P<0.05$.

Results

Dry matter consumed yields

Multiple N applications of 25 to 100 kg/ha after each grazing increased ($P<0.05$) DM consumed at both sites by a total of 1.7 to 5.3 t DM/ha for the summer irrigation periods (Tables 1 and 2). Applications of N after every second grazing resulted in increased ($P<0.05$) DM consumed at both sites by a total of 1.9 to 4.6 t DM/ha (Tables 1 and 2). At Site 1 during Years 1 and 2, applications of 25 kg N/ha after each grazing, and 50 kg N/ha after every second grazing were the most efficient (11 to 19 kg DM/kg N applied) (Table 1). Similarly, at Site 2 during Years 1 and 2, applications of 25 kg N/ha after each grazing, and 50 kg N/ha after every second

Table 1 Site 1: total pasture consumed, extra pasture grown, N efficiency and cost (based on urea supplied and applied at AU$580/t) of extra pasture after applications of different amounts of nitrogen after each or every second grazing.

N treatment (kg/n grazings)	Total N (kg N/ha)	Total consumed (t DM/ha)	Extra consumed (t DM/ha)	N efficiency (kg DM/ha)	Cost ($/kg DM)
Year 1					
0	0	7.70	0	-	-
25	225	10.32	2.62	11.6	0.11
50	450	11.49	3.79	8.4	0.15
75	675	13.03	5.30	7.9	0.16
100	900	12.90	5.20	5.8	0.22
50/2nd	250	10.46	2.76	11.0	0.11
100/2nd	500	11.51	3.81	7.6	0.17
150/2nd	750	11.88	4.18	5.6	0.23
200/2nd	1000	12.30	4.60	4.6	0.27
LSD ($P<0.05$)	-	1.34	-	-	-
Year 2					
0	0	8.44	0	-	-
25	150	11.12	2.68	17.9	0.07
50	300	11.04	2.60	8.7	0.14
75	450	12.07	3.63	8.1	0.16
100	600	11.84	3.40	5.7	0.22
50/2nd	150	11.29	2.85	19.0	0.07
100/2nd	300	11.38	2.94	9.8	0.13
150/2nd	450	11.68	3.24	7.2	0.18
200/2nd	600	12.22	3.78	6.3	0.20
LSD ($P<0.05$)	-	1.17	-	-	-

Table 2 Site 2: total pasture consumed, extra pasture grown, N efficiency and cost (based on urea supplied and applied at AU$580/t) of extra pasture after application of differing amounts of nitrogen after each or every second grazing.

N treatment (kg/n grazings)	Total N (kg N/ha)	Total consumed (t DM/ha)	Extra consumed (t DM/ha)	N efficiency (kg DM/ha)	Cost ($/kg DM)
Year 1					
0	0	9.10	0	-	-
25	175	10.76	1.66	9.5	0.13
50	350	11.49	2.39	6.8	0.19
75	525	12.80	3.70	7.0	0.18
100	700	12.09	3.00	4.3	0.29
50/2nd	150	11.42	2.32	15.5	0.08
100/2nd	300	10.98	1.88	6.3	0.20
150/2nd	450	12.16	3.06	6.8	0.19
200/2nd	600	11.91	2.81	4.7	0.27
LSD ($P<0.05$)	-	1.27	-	-	-
Year 2					
0	0	6.25	0	-	-
25	125	8.17	1.92	15.4	0.08
50	250	8.82	2.57	10.3	0.12
75	375	9.83	3.58	9.5	0.13
100	500	9.39	3.14	6.3	0.20
50/2nd	150	8.57	2.32	15.5	0.08
100/2nd	300	9.77	3.52	11.7	0.11
150/2nd	450	10.15	3.90	8.7	0.14
200/2nd	600	9.51	3.26	5.4	0.23
LSD ($P<0.05$)	-	1.38	-	-	-

Table 3 Apparent water use efficiencies at Sites 1 and 2 during summer for Years 1 and 2 after application of different amounts of nitrogen after each or every second grazing.

N treatment	Site 1* (t DM/ML)	Improvement (%)	Site 2** (t DM/ML)	Improvement (%)
Year 1				
0	0.85	-	1.34	-
25	1.14	34	1.59	19
50	1.27	49	1.69	26
75	1.44	69	1.88	40
100	1.43	68	1.78	33
50/2nd	1.16	36	1.68	25
100/2nd	1.27	49	1.61	20
150/2nd	1.31	54	1.67	25
200/2nd	1.36	60	1.74	30

* Total water (irrigation and rain) applied from mid-October 2003 to end of April 2004 was 905 mm/ha
** Total water (irrigation and rain) applied from mid-October 2003 to end of April 2004 was 681 mm/ha

N treatment	Site 1* (t DM/ML)	Improvement (%)	Site 2** (t DM/ML)	Improvement (%)
Year 2				
0	1.06	-	0.86	-
25	1.40	32	1.13	31
50	1.39	31	1.22	42
75	1.52	43	1.36	58
100	1.49	41	1.30	51
50/2nd	1.42	34	1.18	37
100/2nd	1.43	35	1.35	57
150/2nd	1.47	39	1.40	63
200/2nd	1.54	45	1.31	52

* Total water (irrigation and rain) applied from beginning November 2004 to mid April 2005 was 795 mm/ha
** Total water (irrigation and rain) applied from mid-November 2004 to end of April 2005 was 724 mm/ha

grazing were the most efficient (10 to 16 kg DM/kg N applied) (Table 2).

Water use efficiency

The use of N fertiliser improved pasture WUE, regardless of the amount of N applied. At Site 1 during Year 1, WUE ranged from 0.85 (with no N) to 1.44 t DM/ML (with 75 kg N/ha per grazing), representing an improvement of up to 69% for a given amount of summer water (905 mm/ha irrigation plus rain) (Table 3). In Year 2, WUE ranged from 1.06 (with no N) to 1.54 t DM/ML (with 200 kg N/ha every second grazing).

The WUE at Site 2 ranged from 1.34 (with no N) to 1.88 t DM/ML (also with 75 kg N/ha per grazing), representing an improvement of up to 40% for a given amount of summer water (681 mm/ha irrigation plus rain). For Year 2, WUE ranged from 0.86 (with no N) to 1.40 t DM/ML (with 150 kg N/ha every second grazing).

Discussion

These experiments suggest that a lack of plant available N during summer limits perennial ryegrass DM yields because pasture DM consumed increased consistently when N fertiliser was applied during summer. Increasing rates of fertiliser N increased yields of pasture DM consumed in a similar fashion to N applied during autumn, winter and spring in similar environments to the current experiments (McKenzie *et al.* 1999, 2003). Nitrogen applied at 25 kg/ha per grazing and 50 kg/ha every second grazing gave the best response efficiencies of between 10 to 19 kg DM/kg N. These N rates also proved to be the most economical costing between $70 and $130/t DM consumed. By comparison, high N applications (100 to 200 kg/ha) every second grazing were relatively inefficient and less economical. Similar principles with respect to the highest N response efficiencies at lower rates of applied N (e.g. 25 kg N/ha) are documented for autumn, winter and spring applied N (McKenzie *et al.* 1999, 2003). It should be cautioned that the high rates of N tested in these experiments pose an environmental risk. Numerous studies have shown that as N fertiliser rate is increased beyond the capacity of the soil-plant system to utilise this N, an increasing proportion is susceptible to loss, either as leaching, denitrification or volatilisation (Eckard *et al*. 2004).

During the development of the experiment to a second year, it was believed that the short grazing rotations set by the farmers in Year 1 disadvantaged pasture DM consumed yields and N response efficiencies, hence the decision to set grazing rotations to the three-leaf stage of ryegrass development. It appears that the longer grazing rotations adopted in Year 2 (21 to 28 days, based on perennial ryegrass 3- leaf stage), relative to Year 1 (14 to 21 days), resulted in more efficient N responses. During Year 1 the grazing rotations adopted by the farmers equated to grazing at the 1- to 3-leaf stage of perennial ryegrass development. Recent data, which bases grazing rotations on when perennial ryegrass reaches the 3-leaf stage of development, suggest that higher DM yields are obtained than when grazing rotations are too short (e.g. 1- to 2-leaf stage of development) (Fulkerson & Slack 1994; McKenzie *et al.* 2006).

It is acknowledged that water demand increases as pasture growth in response to N increases. However, the practical nature of this study precluded monitoring the water use of individual treatments and correspondingly scheduling irrigation. Irrigation scheduling was based on the treatment receiving 50 kg N/ha each grazing so this may have 'over watered' the control and 25 kg N/ha per grazing treatment and 'under watered' the remaining treatments. With this in mind, N fertiliser improved the conversion of a fixed amount of water (irrigation plus rain) into pasture DM, regardless of the rate at which it was applied. It is cautioned that while the greatest improvements in WUE occurred at relatively high N applications (75 kg N/ha every grazing), both economics, N response efficiencies and potential environmental impacts should be considered together with WUE when selecting the best rate of N to apply under practical conditions.

ACKNOWLEDGEMENTS

The study was supported by the 'Nullawarre Irrigation Group' in southwest Victoria. Funding was provided by 'Water for Growth' and WestVicDairy, and technical and scientific input by the Victorian Department of Primary Industries. Fertiliser for Year 2 was sponsored by Incitec/ Pivot and Hifert.

REFERENCES

Earle, D.F.; 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 and Animal Husbandry 19*: 337-343.

Eckard, R.J.; Edis, R.; White, R.E.; Smith, A.; Chapman, D.F. 2004. Nitrate leaching from temperate grass and clover dairy pastures in south eastern Australia. *Australian Journal of Agricultural Research 55*: 911-920.

Fulkerson, W.J.; Slack, K. 1994. Leaf number as a criteria for determining defoliation time for *Lolium perenne*: 1 Effect of water soluble carbohydrates and senescence. *Grass and Forage Science 49*: 373-377.

GenStat Committee, 2003, 'GenStat® Release 7.1.' VSN International Ltd, Oxford.

McKenzie, F.R.; Ryan, M.J.; Jacobs, J.L.; Kearney, G. 1999. Effect of rate and time of nitrogen application from autumn to midwinter on perennial ryegrass-white clover dairy pastures in western Victoria. 1 Growth and composition. *Australian Journal of Agricultural Research 50*: 1059-1065.

McKenzie, F.R.; Jacobs, J.L.; Kearney, G. 2003. Long-term effects of multiple applications of nitrogen fertiliser on grazed dryland perennial ryegrass/white clover dairy pastures in south-west Victoria. 2. Growth rates, dry matter consumed, and nitrogen response efficiencies. *Australian Journal of Agricultural Research 54*: 471-476.

McKenzie, F.R.; Jacobs, J.L.; Kearney, G. 2006. Effects of spring grazing on dryland perennial ryegrass/white clover dairy pastures. 1. Pasture accumulation rates, dry matter consumed yield and nutritive characteristics. *Australian Journal of Agricultural Research 57*: 543-554.

Ward, G.; Burch, S., Jacobs, J.; Ryan, M.; McKenzie, F.; Rigby, S. 1998. Effects of sub-optimal irrigation practices on dairy pasture production in south west Victoria. pp. 254-257. *In*: Proceedings of the 9th Australian Agronomy Conference.