Evaluation of the Water Use Efficiency of Dairy Production Using Crops and Pastures

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Abstract

This study evaluated the water use efficiency (WUE) of milk and forage production from a range of temperate and tropical forages on 5 dairy farmlets and a small field plot study located at Mutdapilly Research Station in south east Queensland. The feedbase had a greater affect on the WUE of milk production than the volume of irrigation and rainfall received. For instance, the high irrigation, high quality temperate pasture based (M4) farmlet received an additional 36% volume of water when compared to the crop based feedlot (M5) farmlet, though milk production from forage was 30% less. This difference in efficiency occurred in part from the superior WUE of the irrigated maize (*Zea mays*) summer crop with 3.4 t DM/ML and lucerne (*Medicago sativa*) winter crop with 2 t DM/ML, and the increased efficiency of herbage utilisation from the conservation of crops compared with grazing of pastures. The raingrown (M1) farmlet's WUE of milk production was relatively high, however forage production was limited and consequently milk yield was comparatively low. The range in herbage WUE associated with forage species was consistent between the farmlet and small plot studies. Farmers are challenged with striking a balance between selecting forage types that optimise WUE and those that increase diet quality.

Media summary

The selection of forage species on the basis of WUE can be used as a strategy to optimise the WUE of milk production in the sub tropical dairy regions of south east Queensland.

Key Words

Water Use Efficiency Crops Pastures Dairy

Introduction

The dairy regions of Queensland are located in a sub tropical environment and are typified by unreliable and predominantly a summer distribution of rainfall. Irrigation water is vital for the consistent growth of high quality herbage to satisfy the herd's dietary requirements for production of milk all year round. In recent years considerable publicity has surrounded the use of irrigation water for primary production and regulatory bodies are actively monitoring and administering its use. Users of irrigation are required to improve the efficiency of water use and minimise nutrient loading and runoff to the environment. At the same time, dairy farmers need to triple production to remain profitable post-deregulation (Hoekema et al. 2000). This paper considers options to increase milk production by defining the efficiency of milk and herbage production for a range of forages using data collected from 5 farmlets (Andrews et al. 2003) and a small field plot study located in south east Queensland.

Methods

The farmlet and small field plot study were located at Mutdapilly Research Station in south east Queensland (27^{o}46' south, 152^{o}40' east; altitude 40 m). Calculated WUE does not include water used to produce stubble, roots or senescent material, or stored soil moisture content at the commencement of the study.

Farmlets

The soil type was a self-mulching Black Vertosol containing 70 to 80% clay to a 1 m profile. The 5 farmlets included (M1) raingrown tropical grass pastures and forage oats, (M2) 20% of the farm area irrigated and planted to annual ryegrass and 80% raingrown tropical grass pastures, (M3) 10% of the farm irrigated and planted to forage crops and annual ryegrass, and 90% to raingrown forage crops, (M4) 90% of the farm irrigated and planted to temperate pastures and summer forages, and (M5) a feedlot whose feedbase consists of irrigated temperate and tropical crops. Each farmlet was comprised of 20 cows and received an additional 3 t/head/year of concentrate to achieve target production goals (Andrews et al. 2003).

Defoliation practice, irrigation and fertiliser management for a forage species were managed similarly between farmlets. Generally 25 mm of irrigation water was applied using a travelling gun every 10 to 28 d depending on plant requirements. The prairie (*Bromus unioloides*)/chicory (*Cichorium intybus*)/lucerne/fescue (*Festuca arundinacea*) mixture did not receive irrigation from December 2002 to March 2003 due to restrictions as a result of drought. Temperate pastures and sorghum were strip grazed in most instances to optimise herbage utilisation while tropical grass pastures were rotationally grazed to foster the selection of high quality forage.

Forage utilisation was determined pre- and post-defoliation and prior to harvest of crops. Milk production for each farmlet was measured daily. The volume of milk produced from forage for each farmlet was calculated using reverse feeding standards, and then divided by the total of irrigation and rainfall to determine WUE of milk production. Conversion factors were used to estimate milk production from forage to calculate WUE of herbage production; the volume of milk produced from 1 kg dry matter (DM) was 1 L for ryegrass, prairie grass and lucerne, 0.9 L for oats, raingrown lablab (*Dolichus purpureus*), maize silage, lucerne silage, 0.8 L for forage sorghum, rhodes grass, and 0.7 L for raingrown sorghum (*Sorghum vulgare*) (R. Moss pers. Comm.). The WUEs of milk production for winter and summer were not included for the feedlot M5 farmlet because the forage conserved during winter or summer may not have been fed to the herd for several months.

The experimental period described herein is April 2002 to March 2003. Cumulative daily evaporation from a Class A pan during the sampling period was 2147 mm and this was 25% above Amberley's 60 year long term average. Rainfall received during the same period was 531 mm and this was 38% below average.

Small plot field study

A total of 40 plots, each 5 m x 5 m were laid out in a randomised block design with eight treatments and four replicates. A 5 m buffer strip surrounded each plot to reduce variation in growth caused by shading, nutrient and moisture use. In April 2001 plots were sown to each of (a) annual ryegrass cv. Aristocrat at 30 kg/ha, (b) perennial ryegrass cv. Impact at 20 kg/ha, (c) prairie grass cv. Matua at 60 kg/ha, (d) temperate annual crop oats cv. Nugene at 60 kg/ha, (e) temperate perennial legume white clover cv. Haifa at 6 kg/ha, (f) lucerne cv. Sequel at 15 kg/ha. In December 2001 replicate plots were sown with (g) tropical grass rhodes cv. Callide at 7 kg/ha and as stolons, (h) tropical forage maize cv. 31M10 at 26 kg/ha, (i) forage sorghum cv. Superdan at 15 kg/ha, and (j) tropical annual legume lablab bean cv. Highworth at 30 kg/ha. Oats was replanted at a similar rate in May 2001 to compensate for the initial low plant densities arising from lower than adequate plant establishment rates.

Irrigation scheduling and defoliation practice was specific to each species. Irrigation occurred when the daily rate of soil moisture extraction in the upper 10 cm of the active root zone of each species decreased following the peak level of extraction. The volume of irrigation water applied generally restored soil moisture levels to field capacity.

Total rainfall during the study was 679 mm (30% below 60 year average for Amberley) and 2253 mm of evaporation (18% above 60 year average for Amberley) from April 2001 to May 2002.

Results

Farmlet – WUE of forage and calculated milk production for each forage

During winter, raingrown oats for farmlets M3 and M1 maximised WUE with 3.5 and 1.9 t DM/ML respectively, and oats in M3 maximised WUE of milk production with 3173 L/ML (Table 1). The herbage efficiencies of the remaining irrigated temperate species ranged from 1.1 to 1.6 t DM/ML and efficiencies of milk production ranged from 1000 to 1600 L/ML. Greatest WUE was recorded during summer for raingrown sorghum with 4.3 t DM/ML and 2801 L milk/ML, and maize with 3.4 t DM/ML and 3055 L milk/ML. The lowest WUE of herbage was recorded by the prairie/chicory/lucerne/fescue mixture with 0.9 t DM/ML. The lowest efficiency of milk production was for the tropical rhodes sward for M1 at 888 L/ML.

Table 1. Forage utilisation (t DM/ha), estimated milk production (L/ha), rainfall and irrigation (ML/ha) and WUEs for herbage production (t DM/ML) and milk production (L/ML).

		Forage	Estimated milk			WUE	
Species	Farmlet	yield	production	Rainfall	Irrigation	Herbage	Milk
Temperate species from April to November 2002							
Annual ryegrass	M2	8.9	8919	1.8	3.8	1.6	1599
	M3	7.9	7926	1.8	3.8	1.4	1421
	M4	7.5	7505	1.8	3.8	1.3	1345
Oats	M1	2.2	2013	1.2	-	1.9	1692
	M3	6.5	5756	1.8	-	3.5	3173
Prairie/lucerne	M3	7.3	7346	1.3	3.9	1.4	1391
Lucerne/perennial ryegrass	M4	4.5	4497	1.3	2.9	1.1	1070
Prairie/chicory/lucerne/fescue	M4	5.5	5503	1.6	3.2	1.2	1165
Lucerne	M5	8.0	7200	1.5	4.8	1.3	1140
Tropical species from December 2002 to March 2003							
Forage sorghum	M2	10.1	7544	3.5	1.2	2.1	1610
	M3	8.8	5702	2.0	-	4.3	2801

Rhodes grass	M1	4.3	3189	3.6	-	1.2	888
	M2	4.2	3156	3.2	-	1.3	996
Lablab	M3	6.6	5585	2.8	-	2.4	2008
Maize	M5	19.6	17550	2.2	3.5	3.4	3055
Prairie/lucerne	M3	5.6	5551	3.2	1.6	1.2	1171
Lucerne/perennial ryegrass	M4	4.0	4038	2.4	1.7	1.0	985
Prairie/chicory/lucerne/fescue	M4	5.0	4979	3.9	1.5	0.9	924
Lucerne	M5	10.0	9000	2.5	2.4	2.0	1841

WUE of milk production for each farmlet

Farmlets M2 and M3 recorded the greatest WUE of milk production from forage during winter with 2198 and 2174 L/ML respectively (Table 2). During the summer season farmlet M1 continued to record the greatest efficiency of milk production with 1014 L/ML compared to M2, M4 and M3 with 724, 707, and 513 L/ML respectively. M5 recorded the greatest efficiency when calculated for the entire sampling period with 2049 L milk/ML, followed by M1 with 1376, M3 with 1153, M4 with 1083, and M2 with 1073.

Table 2. Milk production from forage (ML), rainfall and irrigation (ML), and WUE (L/ML) during winter (June to November 2002), summer (December 2002 to March 2003), and from June 2002 to March 2003 (2002/2003).

Season	Farmlet	Milk from forage	ML/farmlet		
			Rainfall	Irrigation	WUE
Winter	M1	27.5	12.5	-	2198
	M2	30.6	13.9	5.6	1568
	M3	44.9	14.3	6.3	2174
	M4	47.7	11.6	21.9	1426
Summer	M1	28.8	28.4	-	1014

	M2	20.0	25.7	1.9	724
	M3	16.9	30.7	2.3	513
	M4	21.6	21.4	9.2	707
2002/2003	M1	56.3	40.9	-	1376
	M2	50.5	39.6	7.5	1073
	M3	61.8	45.1	8.6	1153
	M4	69.3	32.9	31.1	1083
	M5	97.1	21.3	26.1	2049

Small plot field study – WUE of forage production

The WUEs of the temperate species ranged from a maximum 1.2 t DM/ML for irrigated annual ryegrass to a minimum of 0.7 t DM/ML for white clover (Table 3). The greatest WUE recorded during the study was the tropical maize crop harvested on 12 March 2002 with 4.6 t DM/ML. Defoliation of the remaining tropical species ended on the 8 May 2002 and the WUE of rhodes grass was 1.7, for sorghum 1.6 and for lablab 0.9 t DM/ML.

Table 3. WUE (t DM/ML), rainfall (ML) and irrigation (ML) cumulative for the defoliation period.

Species	Defoliation period	Forage yield	Rainfall	Irrigation	WUE
Annual ryegrass	May – December 01	13	3	8	1.2
Lucerne	May 01 – June 02	19	6.6	11	1.1
Oats	May – December 01	9	3	6.4	0.9
Perennial ryegrass	May 01 – June 02	20	6.6	11.8	1.1
Prairie	May 01 – March 02	14	5.8	12	0.8
White clover	May 01 – June 02	16	6.6	15.2	0.7
Maize	December 01 - March 02	18	1.7	2.3	4.6

Sorghum	December 01 - May 02	12	2.8	4.4	1.6
Rhodes	December 01 - May 02	11	2.8	3.4	1.7
Lablab	December 01 - May 02	7	2.8	5.1	0.9

Conclusion

Of the irrigated temperate species evaluated during winter, irrigated annual ryegrass was most water use efficient with 1.3 to 1.6 t DM/ML in the farmlet and 1.2 t DM/ML in the small plot field studies respectively. The ability of this species to establish quickly from seed and withstand defoliation 6 weeks after germination, coupled with high growth rates during spring, contributed to high WUE. In comparison the WUE of the tropical maize and sorghum forages were twice that of the temperate species. The greatest efficiency of herbage production for the farmlet study was raingrown sorghum with 4.3 t DM/ML, and for the small plot study was maize with 4.6 t DM/ML. Maximum WUE is likely to be achieved from a 'double-crop' system that includes irrigating annual ryegrass during the winter season followed by irrigated maize during summer.

The greatest WUE of milk production from farmlets was for the feedlot based on crops (M5) and the dryland grazing farmlet (M1). However for dryland pasture grazing milk yield was comparatively low. By contrast milk yield was high with the high irrigation pasture M4 farmlet, though WUE of milk production was less than 1100 L/ML.

The findings from this study have shown that by selecting forage species on the basis of WUE, the WUE of milk production will be increased. However, exclusively selecting these species that are generally lower in forage quality will reduce milk yield. Farmers are confronted with a challenge of finding the balance between optimising WUE and maximising milk yield.

References

Andrews RJ, Busby GJ, Callow MN, Chataway RG, Cowan RT, Todd H, Walker RG and Waters WA (2003). Sustainable Dairy Farm Systems for Profit. *Australian Farming Systems Conference*, Toowoomba, Queensland.

Hoekema M, Jelbart M, Clark D and Worsley A (2000). Future Farming Systems – options for a deregulated market. *Final report to the Dairy Research and Development Corporation*, August 2000.