

Resource Efficient Dairying trial: measurement criteria for farm systems over a range of resource use

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Abstract

The aim of the Resource Efficient Dairying (RED) trial is to measure the productivity, economic and environmental effects of different feed inputs and management processes on a dairy farm. This is a long-term systems trial located at Scott Farm (Dexcel Research Farm) established on 1st June 2001 and expected to continue until 2006. Trial design was based on six systems that have an allowance of up to 200 kg nitrogen (N)/ha (excluding the low input treatment). They are: low input (no N fertiliser, heifers grazed-on and 2.3 cows/ha); control (3 cows/ha); standoff (3 cows/ha); low supplement input (5 t dry matter (DM) maize silage/ha, 3.8 cows/ha); moderate supplement input (10 t DM maize silage/ha; 5.2 cows/ha); and high supplement input (15 t DM maize silage + 5 t soymeal/ha; 6.9 cows/ha). The last two systems have irrigation available to boost pasture production. All systems were designed to operate at a common comparative stocking rate (CSR) of 85 kg liveweight (LW)/t DM. Two seasons' data have shown that increasing the stocking rate (SR) by 1.5 cows/ha from 3.8 to 5.3 cows/ha, plus extra feed, increased output by 90 and 184 kg milk solids (MS)/total ha in the two years, when the extra area required to supply the extra feed is included in the calculation of kg MS/ha. However the further increase to 6.9 cows/ha plus extra feed produced less MS/total ha than the system stocked at 3.8 cows/ha. Calculations of economic farm surplus (EFS) and return on assets (ROA) reveal that when the payout is \$3.50/kg MS the low input system is competitive irrespective of land price (\$18000 or \$37000/ha) or supplement cost (18 c or 24 c/kg DM). Conversely at a higher payout of \$4.50/kg MS the treatment supplemented with 10 t maize silage DM/ha is competitive over the range of land prices and supplement costs tested.

Keywords: dairy cows, economic evaluation, maize silage, milk solids, nitrogen fertiliser, stocking rate

Introduction

Farmers have developed a range of dairy production systems suitable to the strategic plans for their farms, which is often governed by the physical aspects and climate of the area. Systems include low input, self-contained; grazing dry stock off-farm; increasing feed grown on-farm with the aid of irrigation, cropping or N fertiliser; and importing feed from off-farm sources. The higher input systems have developed where:

- Marginal returns on extra milk production are greater than marginal cost of extra feed
- They allow more profitable use of existing land, cows, plant, and labour
- Farmers wish to avoid the risk and cost associated with buying more land
- Farmers wish to reduce production variation between seasons
- Farmers wish to acquire additional Fonterra shares.

Milk solids/ha is the product of SR, expressed as cows per hectare, and MS per cow, and increasing either or both will increase MS per hectare, provided that sufficient feed per hectare is provided to avoid the negative relationship between SR and production/cow (McMeekan 1961). Supplement brought onto the farm will support high MS production per cow and per ha at the high SRs needed to achieve high levels of pasture utilisation (Stockdale 1995).

Supplement input to a system can be used to control pasture residuals and maintain pasture conditions for optimal growth (Van der Poel 1997). In addition, supplements allow for a higher SR that would increase pasture utilisation and extend lactation thereby achieving high MS responses to supplements (Deane 1999).

Supplements will increase the total farm feed supply, and may prevent periods of underfeeding of the cows, which would otherwise have occurred at the higher stocking rate. The MS/cow response can be optimised by high breeding worth (BW) cows, which give higher responses to extra feed at higher yields per cow than low BW cows (Macdonald *et al.* 2005).

The RED trial was designed to monitor the effects on MS production, economic performance and environmental impacts of increasing feed inputs into pastoral based dairy systems.

Materials and methods

The six experimental farmlets are located at Dexcel's Scott Research Farm, Newstead, Hamilton. All treatments are designed to offer a CSR of 85 kg LW/t total DM, the level at which EFS is optimised (Speight 2002). Feed inputs and SR/ha (ha of home pasture) are shown in Table 1. The CSR is based on an average LW of 500 kg per cow. Treatment herds of 21 Holstein-Friesian cows were established on 1st June 2001, and were balanced for age, expected calving date, LW, condition score, BW and somatic cell count. Annual culling allows for 25%

Table 1 Resource efficient dairying trial design, area, SR and predicted feed inputs to achieve intensification with a common CSR (85 kg LW/t DM).

Treatment	Pasture (t DM/ha)	Supplement (t DM/ha pasture)	Area (ha)	Stocking rate (cows/ha pasture)
A. Control	17.5	0	7.0	3.0
B. Standoff pad	17.5	0	7.0	3.0
C. Low input ^a	15.0	0	9.0	2.6
D. Low supplement	17.5	5*	5.5 (+1.1) ^c	3.8 (3.2) ^d
E. Moderate supplement ^b	20.5	10*	4.0 (+2.1)	5.2 (3.4)
F. High supplement ^b	20.5	20**	3.0 (+3.7)	6.9 (3.1)

^a Treatment C has four replacement yearling heifers grazed on the farmlet (2.3 cows/ha, 2.6 allowing for heifers), and receives no N fertiliser.

^b Farmlets E and F are irrigated during periods of water deficit.

^c Area given as pasture grazed, and area required to grow supplement feed in parenthesis.

^d Stocking rate expressed as grazed area, and total area shown in parenthesis.

* Maize silage fed in trolleys in paddock.

** Maize silage (19 t DM/ha/yr) + Soybean meal (1 t DM/ha/yr) fed in trolleys in paddock.

replacements entering each herd per year. Treatment B has a standoff pad that is utilised in late-winter and early-spring, under a set of decision rules intended to decrease nitrate leaching from the farmlet paddocks, and to minimise pugging damage and protect soil structure. Treatment C has four replacement yearling heifers grazed on the farmlet.

The pastures were sown in May 2000 with 18 kg/ha Bronsyn perennial ryegrass (*Lolium perenne*), 1.5 kg/ha Grasslands Sustain white clover (*Trifolium repens*) and 1.5 kg/ha Aran white clover (*Trifolium repens*). All treatments except treatment C receive up to 200 kg N/ha annually.

Pasture mass is assessed visually each week, and calibrated against actual mass cut from ten quadrats (each 0.2 m²), four post-grazing and six pre-grazing. The quadrats are cut to ground level with an electric handpiece, washed and oven dried for 48 hours at 105°C. Pasture and supplement are sampled monthly for feed quality analysis by near infrared spectrometry (NIRS).

System efficiencies, feed utilisation (FU, kg DM eaten/kg DM grown) and feed conversion efficiency (FCE, kg MS/t DM eaten) were calculated. The calculation was based on pasture mass grown (from visual estimation) and MS production. Factorial energy requirements were summed for each treatment based on cow LW and production level (McDonald *et al.* 1995). The energy content (MJ ME/kg DM) of the respective treatments (obtained from NIRS analysis) was used to define the quantity of DM required (Jensen *et al.* 2005).

Milk yield/cow was measured by weekly herd tests, with samples analysed to determine crude protein, fat and lactose concentration using a Milkoscan 133B analyser (Foss Electric, Denmark). For treatments D, E, and F the calculated area required to grow the maize silage and the soybean used were added to the farmlet area of pasture to give total area required to support the

cows on that farmlet. Milksolids yields for these treatments were calculated as MS/cow x cows/total area (area of farmlet plus cropped area).

Live weight and condition score of each cow were measured fortnightly at the morning milking. Cow health was closely monitored throughout the trial, and a proactive animal husbandry policy applied across all herds (e.g. in-line dispensing of bloat oil and zinc for prevention of bloat and facial eczema respectively, during susceptible periods). For the supplemented herds, a ration-balancing model based on NRC data (NRC 1987) was used to ensure that cows were offered appropriate mineral and protein supplements to complement the maize silage. However, soybean meal as a protein supplement was given only to treatment F.

Financial evaluation of the treatments was based on EFS (Dexcel Farm Facts 7-3 2003/2004). Variables related to the systems have been applied to the EFS of the base system (system A). These were applied in order of relationships between cow numbers or production and costs from the Profit Watch database (Prewer pers. comm.) (e.g. labour, scaled up accorded to SR; machinery, scaled up accorded to MS production). Supplements were measured as weight given to the cows. The maize silage costs were taken from ProfitWatch data (Leslie 1999) and were either purchased (\$0.24/kg DM/fed) or grown by the dairy farmer on a runoff (\$0.18 /kg DM/fed).

Economic farm surplus analysis does not account for capital costs or returns, but does include plant depreciation. Incorporating the capital items for each system allows the ROA to be calculated (Table 2). All operational and capital investments are included, with appreciation/depreciation attached to all resources of the system (ROA = operational return + capital return).

System sensitivity is tested by using a range of MS payments, and dividing the resultant EFS by the total

Table 2 Effect of dairy system intensification on financial depreciation and appreciation (crop area is excluded).

	A	B	C	D	E	F
Milking plant @ \$5/kg MS (\$/ha)	5658	5398	5012	7899	11327	13997
Depreciation @6% (\$/ha)	-339	-324	-301	-474	-680	-840
Machinery depreciation @ 14.78 c/kg MS (\$/ha)	-167	-160	-148	-234	-335	-414
Total depreciation (\$/ha)	-507	-483	-449	-707	-1014	-1254
Change compared to control (%)		-5	-11	40	100	147
Land value \$37340	37340	37340	37340	37340	37340	37340
Land value \$18000	18000	18000	18000	18000	18000	18000
Land @ \$37340 appreciating at 4% (\$/ha/yr)	1494	1494	1494	1494	1494	1494
Land @ \$18000 appreciating at 4% (\$/ha/yr)	720	720	720	720	720	720
Shares @ \$5/kg MS	5658	5398	5012	7899	11327	13997
Share appreciation rate (10%)	566	540	501	790	1133	1400
Cows @ \$1020/cow x SR X 2.5% appreciation	76	76	59	98	132	176
Total appreciation (land @ \$37340) \$/ha/yr	2135	2109	2054	2381	2759	3069
Change compared to control (%)		-1	-4	12	29	44

Table 3 Resource efficient dairying trial CSR (kg LW/t DM), MS yield (kg/cow), lactation length (days), FU (% pasture eaten) and FCE (g MS/kg DM eaten) mean of two years - 2002/2003 & 2003/2004.

Treatment	A	B	C	D	E	F
Actual CSR	75	73	64	85	78	85
MS yield	390	363	424	411	427	416
Lactation length	268	263	274	273	280	271
FU	73	69	66	79	75	79
FCE	80	78	84	82	84	81

Table 4 Maize silage and soybean meal fed (t DM/farmlet/yr), area (ha) required to grow maize silage and soybean meal (assuming yields of 24 and 4 t DM/ha respectively), MS yield (kg/cow) and MS yield (kg/ha of pasture and kg/total ha) – mean of 2 years (2002/2003 & 2003/2004).

Treatment	A	B	C	D	E	F
Maize silage fed area (ha)	0	0	0	1.1	2.1	2.6
Soybean fed area (ha)	0	0	0	0	0	1.1
Total area (pasture + crop)	7.05	7.05	8.24	6.59	6.11	6.73
MS yield (kg/cow)*	390 ^a	363 ^a	424 ^c	411 ^b	427 ^c	416 ^b
MS yield (kg/ha of pasture)	1162	1087	987	1573	2215	2867
MS yield (kg/total ha)**	1162	1082	987	1345	1443	1254

* kg MS/cow SED= 14.9, figures with same letters are not significantly different.

** MS yield (kg/total ha) = MS production/actual area required to feed the herd (grazed pasture + cropped area).

feed provision. The regression equation can then be obtained to define a breakeven MS payment and display system risk exposure.

Results

Milksolids production/cow ranged from 363 to 427 kg, for Treatments B and E respectively, as shown in Table 3. Milksolids yield/cow on treatment B was depressed by the adverse effect of the feed pad management on pasture quality (Jensen *et al.* 2004). The actual values for CSR varied from the planned common values of

85 kg LW/t DM, due to higher than expected pasture growths, and the resultant productive efficiencies are shown.

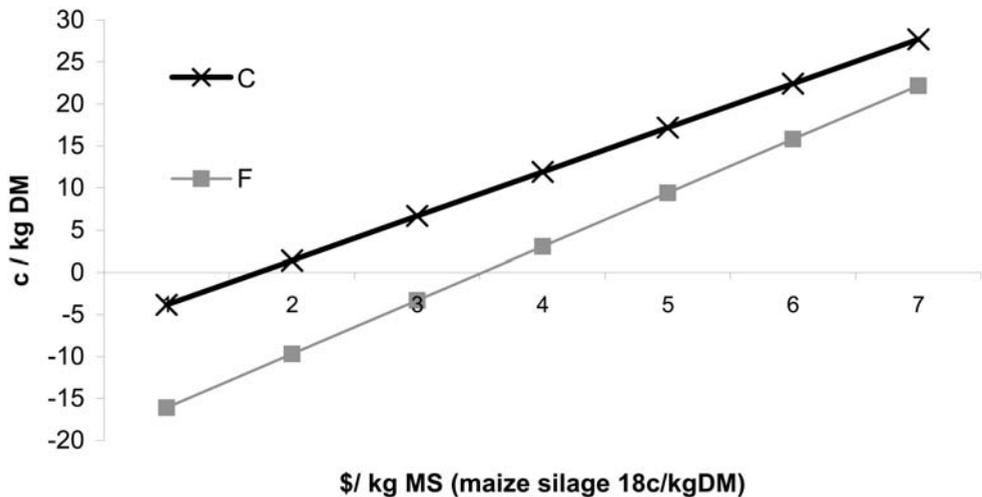
Milksolids productions for each system, calculated per hectare of pasture, and per total hectare, are shown in Table 4.

Financial evaluation

Financial evaluation of the systems is presented in Table 5. Analysis has been made for payments of \$3.50 and \$4.50/kg MS, for maize silage costs of \$0.18 and \$0.24/

Table 5 Economic farm surplus (\$/ha) and ROA (%); mean of 2 years from the RED trial (2002/2003 & 2003/2004) for two sets of costs and returns.

Treatment	A	B	C	D	E	F
A: assumptions \$4.50 kg MS, \$0.18/kg DM maize silage, and land @ \$37000/ha						
EFS	2782	2454	2756	3284	3805	2787
ROA	9.1	8.4	9.3	9.5	9.6	7.2
B: assumptions \$3.50 kg MS, \$0.24/kg DM maize silage, and land \$18000/ha						
EFS	1613	1340	1760	1439	833	-1308
ROA	8.5	7.6	9.5	7.1	4.4	-1.4

Figure 1 Effect of payout on system feed profit of feed input (EFS/kg DM provision), based on supplement cost of \$0.18/ kg DM. Contrasts two treatments from the RED trial.

kg DM, and land prices of \$18000 or \$37000/ha. This analysis is based on pasture area (i.e. cropped area excluded).

System sensitivity results for the respective treatments are shown as the return over the total feed provision (c/ kg DM). The trends for these systems as the payout changes indicate variation in system sensitivity (Figure 1). The analysis clearly shows a variation in system sensitivity by the difference in regression equations of:

$$\text{Treatment C: } y = 5.2568x - 9.1087 \quad (1)$$

$$\text{Treatment F: } y = 6.3777x - 22.458(2)$$

Where $y = c/\text{kg DM}$; and $x = \text{MS payout } (\$/\text{kg})$

By using equations 1, and 2, with \$4.48 as the MS payment the system feed profit (y) becomes \$0.1446 and \$0.0613 for treatments C and F respectively (treatment F has 25.7 t DM/ha of additional feed (18.9 t DM/ha cf 44.6 t DM/ha). When the feed input is multiplied by these values the EFS for both systems is \$2738, however at \$5.00/kg MS the EFS becomes \$3254 and \$4210 respectively. The low input system is less responsive to a shift in payout (multiplier, slope) and has lower overheads to recoup (adder value, rise).

Discussion

Increasing SR and feed inputs resulted in substantial increases in MS yield/ha. Yield of MS/ total ha (pasture + crop) increased by 24% between Treatment A and E compared with an increase of 91% when expressed as MS/ha, of pasture only. Treatment C produced high MS/cow due to high pasture allowance/cow. However, with the lowest SR and low FU efficiency (66%), it had the lowest MS/ha. Of the high input systems (D, E and F), treatment E had the highest MS/cow, and also a relatively high MS/ha because of its high SR. Treatment E achieved high MS/cow and MS/ha through supplement input that allowed a high FU efficiency of 75% leading to a high FCE of 84 g MS/kg DM.

These findings agree with the relationship proposed by Stockdale (1995) that efficient supplement input can give high pasture utilisation rates and high producing and efficient cows. For treatment C to obtain the high DM intake (DMI) required for their level of production, a high pasture allowance (70 kg DM/cow/day) of highly digestible pasture (>11 MJ ME/kg DM) (Kolver & Muller 1998) would be required. The high pasture

allowance is evident as this treatment had an average pasture mass that was consistently above that of the other treatments. Dalley *et al.* (1999) proposed that this would be associated with an increase in pasture residual levels from 1.8 t to 2.7 t DM/ha to change the allowance from 20 to 70 kg DM/cow/day. Feed utilisation for this treatment of 66% supports this relationship.

These results confirm the principle that a low SR will result in high feed allowance/cow, high DMI, high MS yield/cow, high FCE, low FU, and low MS/ha (Macdonald *et al.* 2001). When the SR is increased together with the use of imported feeds to supplement pasture, DMI and MS/per cow, FCE and FU can all be high, and result in high MS/ha.

Economic farm surplus and ROA were maximised when cost effective supplements were used and the payout was relatively high. Conversely a low input system gave the greatest EFS and ROA when supplements were more expensive, and the payout and land value were low.

It is evident that the resource use is cost/return sensitive, and while the analysis shown here is based on two cost/return relationships it holds true that when the payout is \$3.50/kg MS the low input system is competitive irrespective of land price (\$18000 or \$37000/ha) or supplement cost (\$0.18 or \$0.24/kg DM). At a higher payout of \$4.50/kg MS, treatment E supplemented with 10 t maize silage/ha had the highest EFS irrespective of supplement cost. The ROA showed a greater variation due to land value. When the land value is low (\$18000/ha) the low input system had the highest ROA. When the land is valued at \$37340/ha, and the maize silage is costed at \$0.18/kg DM, treatment E has the highest ROA. However when the maize silage is costed at \$0.24/kg DM, the ROA is highest for the low input system (treatment C).

A change in the MS payout has a greater effect on the EFS as the levels of supplement increase. Sensitivity analysis showed that the low input system (treatment C) is less sensitive to changes in MS payout, and has lower system overheads to recover. This aspect is evident from the regression equations (equations 1 & 2) in that both the slope and rise for treatment C is less than F therefore C will be profitable at lower \$/kg MS and has lower overhead costs to recoup than treatment F (\$1.73 and \$3.52/kg MS respective breakeven points). High input systems, treatments D and E are competitive at higher MS payout, and these systems are affected less by a payout change when maize silage cost is held at \$0.18/kg DM. Return on assets analysis, which was based on a land value of \$18000/ha, follows the same trend as for system EFS. However, if the land value is increased to \$37000/ha the high input treatment stocked at 5.3 cows/ha shows a higher return at \$4.50/kg MS and maize

silage costed at \$0.18/kg DM. Effectively this is comparing system profitability when the pasture cost increases from \$0.06/kg DM to \$0.11/kg DM at land prices of \$18000 and \$37340/ha respectively.

Summary

The management of these treatments is generating a wide range in yields of MS/ha due to the large range in feed imported to the milking platform. When physical performance is related to the efficiency of MS production, treatment E is consistently high in terms of pasture utilisation and FCE. The low input system, (treatment C), represents a low financial risk.

These systems are operating across divergent farming philosophies, and market signals may indicate customer preferences. The decision by farmers to adopt a particular system will relate to their personal perspective on environmental issues and to the economic evaluation of the system (and others – labour, machinery, risk). Intensifying dairy systems with higher SRs and more supplementary feed can increase production up to 3000 kg MS/ha of pasture on the milking platform. When the area used to grow the maize was included, the MS/ha of intensive systems was increased by additional maize silage input (+ 281 kg MS/ha; treatment A cf E). However, when the cost/return relationships were analysed, diminishing returns occurred by intensifying above 5.2 cows/ha and 10 t DM maize silage/ha. The profitability of these systems depended on the payout; pasture cost (land price), and maize silage cost. This study highlights that resources needed to support a system may affect its viability and this needs to be explored further with appropriate tools.

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