Integrating high yielding crops into a Taranaki dairying system

K.A. MACDONALD[1], J. CLOUGH[2], J.M. de RUITER[3], C.B. GLASSEY[1] T. SEARS and N. SEARS[4]
[1] *DairyNZ, Private Bag 3221, Hamilton 3240, New Zealand.*
[2] *PGG Wrightson Consulting, P.O. Box 440, Hawera*
[3] *The New Zealand Institute for Plant & Food Research Limited, Private Bag 4704, Christchurch*
[4] *984 Normanby Rd, RD 28, Hawera, Taranaki 4678.*
Kevin.macdonald@dairynz.co.nz

Abstract

Cropping sequences were introduced to a pasture-based dairy system with the aim of improving the annual feed supply, herd productivity and overall profitability. Two farmlets were established on the Waimate West Demonstration Farm (Taranaki) in June 2007 and ran for 5 years. The All-grass farmlet was a pasture-only system (except for 70 kg/cow palm kernel expeller in one year) and the Cropping farmlet had on average 12.5% of the farm cropped each year plus palm kernel expeller (250 kg/cow/year over 3 years). Crop sequences varied in duration from 12 to 28 months. Crops grown were maize (for silage), turnips, chicory, rape, oats, barley and triticale. Stocking rates were 4.0 and 4.2 cows/ha for the All-grass and Cropping farmlets, respectively. Pasture growth for the two farmlets was similar, averaging 16.6 t DM/ha/year. The inclusion of crops added an extra 1.7 t DM/ha/year over the All-grass treatment, averaged over the 5-year trial. In the first 2 years, milksolids (MS) production per hectare was 2% lower for the Cropping farmlet (1145 kg MS/ha) than for the All-grass farmlet (1165 kg MS/ha), but was 11% higher (1237 *vs*. 1112 kg MS/ha) over the next 2 years, increasing to a 27% advantage (1453 *vs.* 1143 kg MS/ha) in the fifth year. Financial analysis indicated a $338 lower operating profit for the Cropping farmlet for the first 2 years but there was an advantage of $560/ha/annum over the next 3 years. Introducing cropping onto a dairy farm system can increase MS production and profit. Careful consideration must be given to the choice of crops to maximise DM yield and minimise the cost of production. Cropping on dairy farms can be successfully implemented, but is dependent on successful crop establishment and efficient feed management. There is potential for sustained higher MS production per cow and higher per ha by including crops in the system, but the potential may not be realised immediately due to reduced area for grazing while the first crops are being established.

Keywords: cropping, milksolids, operating profit

Introduction

New Zealand dairying is generally a pasture-based system, but the use of only pasture has been questioned in relation to cow requirements (Edwards & Parker 1994). Hodgson (1989) reported that there seemed to have been little increase in pasture grown on New Zealand farms over the previous 40 years. Since that publication there seems to have been little further change, and dairy farmers, particularly in the North Island, have been questioning the persistence of pastures (Clark 2011). In the same period, stocking rate has increased from 2.4 to 2.8 cows/ha and milksolids (MS) production per ha has increased by 48% (Clark 2011).

Productivity gains in recent years have been made through the importing of feed from outside the dairy farm. Farmers have sought to reduce their reliance on imported feed by growing crops on-farm to enhance overall DM and energy production, as well as facilitating the introduction of newer, more productive pasture species. Trials where extra feed has been grown in the form of crops have generally been limited to a few crops, mainly maize (Campbell *et al*. 1978; Jensen *et al*. 2004) or maize and turnips (Glassey & Roach 2010). Although maize produces high yields, it has low crude protein and moderate energy levels (MJ ME/kg DM) compared with some crops (Kolver 2000), and conditions are not always suitable for its growth in some districts. Other projects have sought to maximise the yield of cropping sequences (e.g. de Ruiter *et al*. 2009) but have not placed them in a farming systems context.

This project introduced cropping sequences onto the dairy farm to maximise total DM productivity. Forage crops can produce annual yields of 45 t DM/ha/year and high energy/ha (MJ ME) (Minneé *et al*. 2009), but growing crops on the dairy farm requires specialist agronomic and management skills to realise these production gains. The study was designed to monitor the effects of cropping on MS production and the contribution to profit of feed grown in a pastoral-based dairy system.

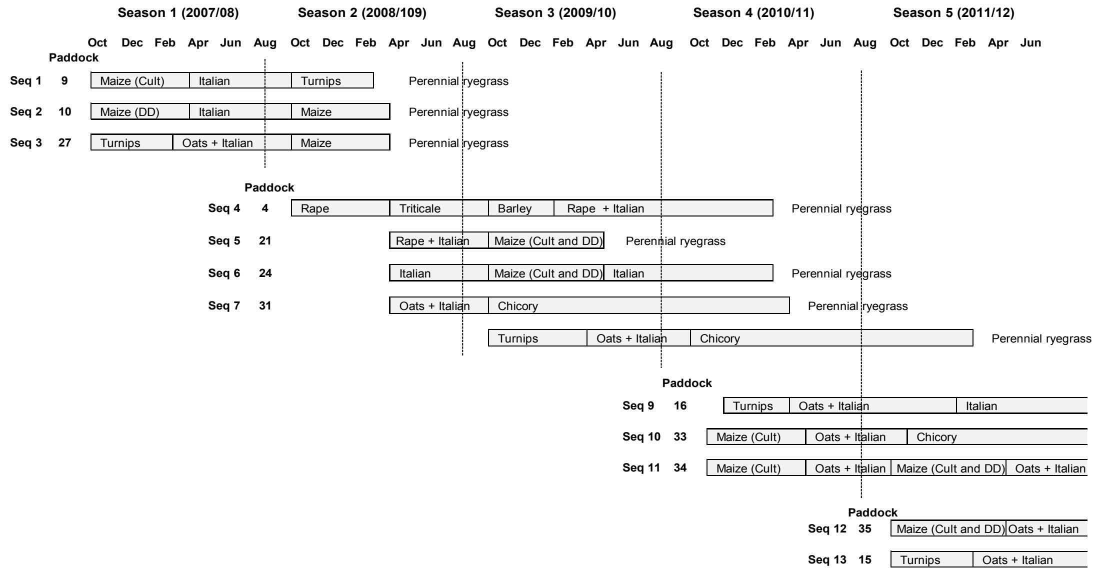

Figure 1: Sequences of crops grown on the Cropping farmlet at Waimate West Demonstration Farm over 5 years (2007-12). Maize establishment was by direct drilling (DD) or into a full cultivated seed bed (Cult).

Materials and Methods

Farmlets

The farmlet-study was located at the Waimate West Demonstration Farm (WWDF), a 34.4 ha property near Manaia in Taranaki (39°31′S, 174°88′E). The soil type is Egmont black loam and is free draining with a flat topography. The pasture is composed of predominantly perennial ryegrass (*Lolium perenne*) with small proportions of white clover (*Trifloium repens*) and other grass species. All paddocks are 0.86 ha and the farm has a central race. Two farmlets (All-grass and Cropping) were established in June 2007 with Jersey cows. Cows were randomly allocated to each treatment and were balanced for age, predicted calving date, liveweight (Lwt) and body condition score (BCS). A replacement rate of 22% was used for both farmlets. Replacements in each milking season were randomly allocated to both farmlets.

The All-grass farmlet was a pasture-only system and had ten paddocks (8.6 ha) and 34 cows, giving a stocking rate (SR) of 4.0 cows/ha. Surplus pasture was conserved as silage and fed to the cows during periods of feed deficit.

Table 1: Farm characteristics, productivity and operating profit ($/ha) of pasture only farmlet (All-grass) and a farmlet with 6.3–17.3% of the area cropped (Cropping) at Waimate West Demonstration Farm over 5 years (2007–12).

	Year 1 & 2 (2007-09)		Year 3, 4 & 5 (2009-12)	
Treatment	All-grass	Cropping	All-grass	Cropping
Stocking rate (cows/ha)	4.0	4.3	4.0	4.2
Farmlet area (ha)	8.6	25.8	8.6	25.8
Number of cows	34	113	34	108
Total pasture grown (t DM/ha)	15.4	15.6	17.3	17.3
Milk production				
Milksolids (kg/cow)	295	268	284	313
Milksolids (kg/ha)	1165	1146	1122	1309
Supplements				
Pasture silage conserved (kg DM/cow)	433	146	426	111
Total income ($/ha)	7915	7860	8182	9487
Total expenses ($/ha)	4097	4376	5100	5847
Operating profit ($/ha)	3909	3571	2980	3540

In the first season (2007/08) the Cropping farmlet had a SR of 4.4 cows/ha but from 2008/09 this was reduced to 4.2. The farmlet supported grazing of 108 cows on 30 paddocks (25.8 ha). A full description of the cropping programme was given by de Ruiter *et al*. (2010). Briefly, this involved crop sequences that varied in duration from 12 to 28 months (Fig. 1) involving maize (for silage), turnips, chicory, rape, oats and triticale. All crops, unless otherwise stated, were established by pre-plant glyphosate and insecticide application followed by direct drilling with a disc seeder. The turnip establishment in the second year was by broadcasting then rolling. Maize seedbeds were prepared by ploughing followed by a double pass of a power harrow before rolling and drilling.

Management

Cows rotationally grazed the pasture as part of normal grazing practice, with the same management applied to both treatments. A set of management decision rules (Macdonald & Penno 1998) was used to ensure that pasture management was consistent between farmlets. In general, cows had access to a fresh allocation of pasture once daily and returned to the same area when the pasture was approximately 2700 kg DM/ha in spring, 4000 kg DM/ha in summer and 3000 kg DM/ha in autumn and winter (all measurements to ground level).

On the All-grass farmlet the total area was available for grazing for the entire year. On both farmlets, surplus pasture was conserved as baled silage and was kept separate for use on the farmlet from which it was harvested.

Pastures in the Cropping farmlet were managed in the same way as for the All-grass farmlet. Crops were managed to minimise pugging damage by allowing animal access to new breaks along a lateral track and then with back-fencing on the break. Animals were managed to achieve high utilisation of feed, however no utilisation measurements were taken to determine actual feed consumed. The maize silage was fed on a feed pad as a supplement to pasture.

Fertiliser

Details of the fertiliser management for all crops are given by de Ruiter *et al*. (2010). A maintenance application of superphosphate (400 kg/ha of Superten 7K; 30 kg/ha P & K) was applied to the pasture area of both farmlets. Approximately 150 kg N/ha (over 6 dressings) was applied to the pasture of both farmlets annually.

Measurements

Milk from cows on each farmlet was collected into separate vats. Volume was recorded by a meter on the tanker at the time of milk collection. Milksolids composition and total MS were reported by the Dairy Co for milk payment purposes.

Pasture cover (kg DM/ha) of each paddock was assessed weekly using calibrated visual assessment. Pasture growth was calculated from the difference in herbage mass between these assessments on paddocks that had not been grazed between the assessments. Pasture that cows were about to graze was sampled monthly from both farmlets to grazing height (approximately 2 to 3 cm), to provide a general description of the quality of pastures eaten. These samples were analysed by near infrared spectroscopy (NIRS) to determine standard nutritional components (eg. organic matter digestibility, crude protein, fibre, soluble sugars).

Crop yield was assessed by cutting quadrats (10 × 0.5 m^2 for grazed crops and 5 × 6 m^2 for maize). Samples were dried to a stable weight at 90˚C and weighed for calculations of plant DM% and DM yield.

Cow Lwt was recorded on a portable cow weighing platform and scale, and body condition (BCS) was determined monthly at approximately 0900 h. Body condition score was assessed on a 10-point scale, where 1 is emaciated and 10 is obese (Macdonald & Roche 2004).

Operating profit

Each year an operating profit (OP) for each farmlet was calculated. Operating profit is the residual from dairy gross farm revenue, once dairy operating expenses are removed. Where actual costs were available and differences were measured between treatments (e.g. use of CIDRs for anoestrous cows and cropping costs) then these were used. Otherwise average cost/cow or if applicable cost per ha were obtained from the DairyNZ Economic Surveys for that year. The payout used was the milk price ($/kg MS) that was announced by Fonterra for each season. No allowance has been made

Table 2: Production from “cropped” area on Cropping farmlet over 5 years (2007–12).

Year	No. paddocks in crop (for part or most of year)	Paddock area in crop (ha)	Area in crop (%)	Crop yield (t/ha)
1	3	1.63	6.3	33.9
2	7	2.86	11.1	24.1
3	5	3.67	14.2	31.0
4	7	4.46	17.3	24.4
5	6	3.53	13.7	19.3

for extra depreciation of plant, equipment and facilities that may be required for a cropping system.

Results and Discussion

Pasture and crop production

Annual pasture growth was similar between farmlets over the five seasons (16.5 and 16.6 t DM/ha for the All-grass and Cropping farmlets, respectively) (Table 1), but averaged 17.3 t DM/ha in Years 3 to 5. Conservation was greatest on the All-grass farmlet with an average of 429 kg DM/cow/year compared with 125 kg DM/cow/year for the Cropping farmlet.

In the third to fifth seasons (2009/10 to 2011/12), palm kernel expeller (PKE; average 250 kg/cow) was bought for the Cropping farmlet. This was to ensure feed supply to the cows in early autumn, in particular before the maize was harvested and became available to be fed to the cows. In one season (2010/11) PKE was also fed to the All-grass farmlet cows (70 kg DM/cow) to overcome a summer feed deficit. In all other years the All-grass farmlet was operated as a closed feed system.

The maximum annual pasture growth that is likely to be achieved in ideal conditions in New Zealand is 20 t DM/ha (Hodgson 1989). In the study described here, the average pasture growth was 15.5 and 17.3 t DM/ha in Years 1 and 2 and 3–5, respectively (Table 1). Although this is below the potential, it was achieved without the use of irrigation. While there was no difference in the amount of pasture grown on the farmlets (Table 1), the Cropping farmlet did produce more feed. Total feed grown on the Cropping farmlet averaged 18.3 t DM/ha/year. The mean yield of crops was 28.4 (± 4.9) t/ha (Table 2). The additional yield from crops was small when averaged over the entire area of the farmlet (1.7 t DM/ha/year) but nevertheless it increased the amount of feed grown. The response to this extra DM grown through the use of crops was 63 g MS/kg DM, which was lower than the 89 g MS/kg DM reported by Glassey & Roach (2010). The proportion of the farm in crop varied from 6.3–17.3% over the five seasons (Table 2). There was an opportunity cost in preparing land for crops and a period when production was low during the early stage of pasture renewal.

Feed value in terms of metabolisable energy (ME) productivity per hectare (GJ/ha) was calculated as the product of the ME and pasture yield/ha. The calculated pasture yield was 198 and 200 GJ/ha/year for the All-grass and Cropping farmlets, respectively. Measures of feed quality and quantity were used to calculate relative production efficiency of each cropping phase. Each of the completed sequences (1–11; Fig. 1) had differing durations from sowing of first crop until harvest of the last crop. It was appropriate to compare average DM accumulation of sequences on a mean daily basis. This varied from 38 to 106 kg/ha/day. Over the life of the project, and including all crops, there was a mean crop productivity of 73 kg DM/ha/day. For most crops, the mean daily growth rate was higher than that achieved from pasture (45 kg/ha/day) on the farm. Calculated mean growth rates for sequences also included periods between crops when little or no growth occurred during crop establishment. Completed sequences containing summer crops of maize (sequences 1, 2, 3, 5, 6, and 11) raised the productivity of the entire sequence. These sequences produced on average 86 (±13.3) kg DM/ha/day. Sequences 7, 8 and 9 contained grazed crop only (turnips, oats + Italian ryegrass and chicory) and the average productivity was lower at 45, 48 and 38 kg/ha/day, and were similar to the mean annual growth rates achieved for pasture.

The moderate to high energy value of maize, together with its high yield, means it is the best crop for filling energy deficits, particularly because it can be stored before use. Conversely, feeds grazed *in situ* such as turnips need to be used when the quality and yield are at their peak, and this may or may not occur at the time of highest feed demand by cows.

The accumulated energy (GJ/ha) of crops for

Table 3: Average NIRS[1] determined quality for pasture and crops at Waimate West Demonstration Farm for 2007-12.

	CP[2]	ADF[3]	NDF[4]	SSS[5]	OMD[6]	ME[7]
Pasture	26.9	23.4	43.2	9.1	84.2	12.0
Chicory	26.8	12.1	19.6	7.8	84.6	12.1
Italian Rye	28.2	33.1	43.4	9.9	85.9	12.4
Triticale	17.4	34.1	56.1	8.1	65.2	9.9
Rape	30.6	18.6	32.0	8.7		12.6
Oats	26.4	25.1	49.8	11.0	79.8	11.8
Turnip Top	21.6	23.9	35.0	16.8		12.5
Turnip Bulb	11.2	27.3	41.2	33.6		13.0
Maize	8.1	22.6	38.0	40.6		11.0

[1]NIRS, Near infrared reflectance spectrometry; [2]CP, Crude protein % DM; [3]ADF, Acid detergent fibre % DM; [4]NDF, neutral detergent fibre % DM; [5]SSS, Soluble sugars and starch % DM; [6]OMD, Organic matter digestibility % DM; [7]ME metabolisable energy MJ/kg DM.

completed sequences ranged between 216 and 620 GJ/ha. Maize crops produced significantly more energy (171–350 GJ/ha) than other crops. For example, turnips produced 133 GJ/ha, compared with spring rape at 143 GJ/ha, triticale 108 GJ/ha, barley 137 GJ/ha, and first winter cut of oats and Italian ryegrass 30 GJ/ha. Averaged individual grazings of Italian ryegrass and chicory contained 26 and 25 GJ/ha, respectively. Crops used for direct grazing (chicory and Italian ryegrass) generally had lower DM yields but were valuable because of the high ME content (> 11 MJ/kg) at a time when pasture ME is lower (summer-autumn) and was grazeable over a long period. Five grazings of chicory in 2009/10 accumulated energy value of 168 GJ/ha, and in the second year (2010/11) 166 GJ/ha over seven grazing events. Subsequent first-year chicory crops were less productive (93 and 125 GJ/ha for sequences 8 and 10, respectively) and 108 GJ/ha for a second year crop in Sequence 8.

Pasture and crop quality

The NIRS and botanical composition data indicated there was no difference in the pasture quality of the pasture offered to the cows on both farmlets (Table 3). Protein content of grazed forages such as Italian ryegrass and chicory were high (Table 3). Most grazed forages were fed in small breaks as a supplement to pasture and therefore protein intake was always non-limiting. However, protein content of maize and turnips were characteristically low and could have reduced MS production due to lower protein intake.

All grazed crops (Italian ryegrass, chicory and rape) had high ME contents because of their high digestibility and low fibre content.

Milksolids production

Milksolids production per cow varied between years from 274 to 315 and 244 to 347 kg MS/cow for the All-grass and Cropping farmlet, respectively (Table 4). This variation for the All-grass farmlet is a feature of rainfed pastoral farming due to variable feed supply (pasture growth) and cows being managed in such a way that production at the end of the season may be curtailed to ensure there is sufficient pasture at the start of the next calving (Macdonald & Penno 1998).

In the first 2 years, MS per hectare were 2% lower for the Cropping farmlet (1145) than for the All-grass farmlet (1165 kg MS/ha), but were 11% higher (1237 *vs.* 1112 kg MS/ha) over the next 2 years. This increased to a 27% advantage (1453 *vs.* 1143 kg MS/ha) in the fifth year (Table 4). This may be a feature of the improved management of the crops and feed availability. The extra MS/cow for the Cropping farmlet meant there was an average advantage of 105 kg MS/ha, but in year 5 it was 310 kg MS/ha (Table 4).

Cow live weight and body condition

Cow Lwt and BCS were similar between treatments. This should not be unexpected as the rules (Macdonald & Penno 1998) governing farmlet management were designed to ensure that cows were treated such that they attained BCS 5 at calving, thus they were dried off at a BCS that would allow this to occur taking into account farm feed cover.

Operating profit

Over the 5 years of the trial the average OP was $3352 and $3552 for the All-grass and Cropping farmlets, respectively (Table 4). It is of interest that after the first 2 years the advantage that the All-grass farmlet had in operating profit was overtaken by the Cropping farmlet in the last 3 years, probably because of increased crop production adding a more timely feed supply, especially in summer. This is probably because it took 2 years for the cropping system to begin to reach equilibrium. In the first two years land was taken out of pasture production

Table 4: Milksolids per cow, per ha and operating profit for a pasture only farmlet (All-grass) and a farmlet with an average of 12.5% of the area cropped (Cropping) at Waimate West Demonstration Farm over 5 years (2007–12).

		All-grass	Cropping
Milksolids (kg/cow)	2007/08	274	244
	2008/09	315	292
	2009/10	280	289
	2010/11	283	302
	2011/12	289	347
	Average	288	295
Milksolids (kg/ha)	2007/08	1083	1070
	2008/09	1247	1221
	2009/10	1105	1210
	2010/11	1119	1264
	2011/12	1143	1453
	Average	1139	1244
Operating Profit ($/ha)	2007/08[1]	5247	4979
	2008/09[2]	2571	2163
	2009/10[3]	2572	2779
	2010/11[4]	4515	5041
	2011/12[5]	1854	2799
	Average	3352	3552

Payout/kg MS. [1]$7.66, [2]$5.20, [3]$6.10, [4]$7.60, [5]$6.05, Years 2007–2009 payout was on milksolids and 2009–2012 on milk price.

for crops with no net benefit to the farmlet. In years 3–5 the system was beginning to add additional feed partly due to increased cropping area (Table 4).

Even though crops were grown to increase feed supply, there were times when this supply of extra feed was not sufficient and PKE was bought to alleviate a temporary feed deficit. If PKE had been used, particularly in the first year when some of the farm was not grazable as crops established, then the negative effects on MS production and OP of the Cropping farmlet may have been reduced.

Campbell *et al*. (1978) described growing maize to increase total feed supply. The main issue with this was the mis-match in nutritive value of the feed available, as maize is generally low in crude protein (Kolver 2000). More recently, Macdonald (1999) described a trial that aimed to produce 1750 kg MS/ha, by the use of increased SR, nitrogen and bought in supplements. The conclusion reached from this trial was that successful strategies are those that are reliant on the availability of low cost, high quality feed. Importantly, an economic analysis identified that the all-grass type farming system is much more stable in year by year operating profit as this system is affected less by fluctuations in MS payout than is a high input farming system. This is also evident from this trial, as a reduction in expected milk price in the last year from $6.35 to $5.20/kg MS (18%) reduced the OP advantage to the Cropping farmlet over the All-grass farmlet, from $1038 to $681/ha. Further, a 20% reduction in average MS price over the 5 years of the project would have given the Cropping farmlet a $63 advantage whereas, if the average MS payout was 20% higher the advantage would have increased to $337/ha. An allowance for depreciation of extra plant, equipment and facilities for the cropping system would have further reduced this difference.

There have been a number of component trials investigating the use of cropping in a whole farm scenario. However this study described is one of only two multi-year farmlet studies in New Zealand that have tried to utilise several crops in a pastoral system. The other is the Super P trial (Glassey & Roach 2010) that had a target of 1750 kg MS/ha from feed grown on the farm. With the strategic use of crops, an extra 0.8 t DM/ha/yr was grown and 1479 kg MS/ha achieved. The Super P farmlet also had a $714/ha greater OP than the comparative benchmark farmlet. In the last year of the trial described here, the Cropping farmlet achieved 1453 kg MS/ha, which is close to that achieved in the Super P trial and also with a greater OP advantage of $945/ha than the All-grass farmlet.

The average comparative stocking rate for both farmlets over the life of the project was 92 and 88 kg Lwt/t DM for the All-grass and Cropping farmlets, respectively. This is greater than the suggested optimum of 77 kg Lwt/t DM by Macdonald *et al*. (2008). Thus there is an indication that there is potential to lower the SR or grow more feed on the farm to further improve profit for both farmlets.

Summary

The use of cropping has been economically beneficial on the WWDF. Planning to get into a cropping system has to take place early, as over the first year or two there will be periods where a large proportion of the farm is out of pasture in new crops thus there is potential for feed shortages. The use of PKE or similar may help alleviate this problem. Importantly the feed has to be bought at an affordable price.

ACKNOWLEDGEMENTS

This project was funded by the Ministry for Primary Industries (Sustainable Farming Fund Project # 08/016), DairyNZ, Taranaki Regional Council and the Foundation for Arable Research. Thanks to DairyNZ, Ballance Agri-Nutrients, Genetic Technologies, NuFarm and PGG Wrightson for technical support and sponsorship. Special thanks to WTARS team (DairyNZ, Hawera) for the pasture, crop and animal measurements.

REFERENCES

Campbell, A.G.; Clayton, D.G.; Macdonald, K.A. 1978. Dairy cattle management. Maize-pasture rotations. *Proceedings of the Ruakura Farmers' Conference 30*: FPP 166.

Clark, D.A. 2011. Changes in pastoral farming practices and pasture persistence – a review. *Grassland Research and Practice Series 15*: 7-15.

de Ruiter, J.M.; Fletcher, A.; Malley, S.; Sim, R.; George, M. 2009. Aiming for 45 t/ha per annum: yield of supplementary feed crops grown in sequences designed for maximum productivity. *Proceedings of the New Zealand Grassland Association 71*: 107-116.

de Ruiter, J.M.; Clough, J.; Macdonald, K.; Glassey, C.B. 2010. Impacts of forage cropping on Taranaki dairy farms. *Proceedings of Australasian Dairy Science Symposium 4*: 326-333.

Edwards, N.J.; Parker, W.J. 1994. Increasing per cow milk solids in a pasture-based system by manipulating the diet: A review. *Proceedings of the New Zealand Society of Animal Production 54*: 267-273.

Glassey C.B.; Roach, C.G. 2010. Increasing home grown feed on non-irrigated Waikato dairy farms: production, profit and feed use of a demonstration farmlet 2006-2009. *In*: Meeting the challenges for pasture based dairying. Eds. Edwards, G.R.; Bryant, R.H. Proceedings of the 4th Australasian Dairy Science Symposium. Christchurch, New Zealand: 179-184.

Hodgson, J. 1989. Pasture production. Proceedings of the 41st Meeting of Dairyfarmers conducted by Massey University: 76-81.

Jensen, R.N.; Clark, D.A.; Macdonald, KA. 2004. Dairying intensification; production responses and financial implications. *Proceedings of the Agronomy Society of New Zealand 34*: 13-20.

Kolver. E. 2000. Nutrition guidelines for the high producing dairy cow. *Proceedings of the Ruakura Farmers' Conference 52*: 17-28.

Macdonald, K.A. 1999. Determining how to make inputs increase your EFS. *Proceedings of the Ruakura Dairy Farmers' Conference 51*: 78-87.

Macdonald, K.; Roche. J. 2004. Condition Scoring Made Easy. Condition scoring dairy herds. Dexcel Ltd. Hamilton, New Zealand. ISBN 0-476-00217-6.

Macdonald, K.A.; Penno, J.W. 1998. Management decision rules to optimise production on dairy farms. *Proceedings of the New Zealand Society of Animal Production 58*: 132-135.

Macdonald, K.A.; Penno, J.W.; Lancaster, J.A.S.; Roche, J.R. 2008. Effect of stocking rate on pasture production, milk production and reproduction of dairy cows in pasture-based systems. *Journal of Dairy Science 91*: 2151-2163.

Minneé, E.M.K.; Fletcher, A.L.; de Ruiter, J.M.; Clark, D.A. 2009. Forage crop sequences for pastoral systems in northern New Zealand. *Proceedings of the New Zealand Grassland Association 71*: 93-100.