DEPARTMENT for ENVIRONMENT, FOOD and RURAL AFFAIRS **CSG 15**

Research and Development

Final Project Report

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Executive summary (maximum 2 sides A4)

(1) Two different systems of organic milk production were studied during the 1998-2002 period. The systems were established at the IGER Ty Gwyn organic dairy farm during the 1998/99 period. The systems were based on either achieving self-sufficiency in both home-grown forage and concentrate feeds (SS system) or the production of home-grown forage and the purchase of concentrate feeds (PC system). The data collected included recording the changes in the soil indices, level of crop production, crop quality, level of milk production, milk quality, animal health and herd reproductive performance of the two systems.
(2) The land areas (including land allocated for rearing the replacement stock) allocated for the SS and PC systems were 51.0 and 43.5 ha, respectively. Separate crop rotations were established for each system with 20% of the total land area within each system maintained as permanent pasture. The breed of dairy cows in the two herds was the Holstein-Friesian.
(3) The strategy for the utilisation of the slurry and farmyard manure was to apply the nutrient sources to the fields with the lowest P and K indices. No major changes were recorded during the project in the soil indices of fields in the SS system with average indices of 2, 2- and 3 maintained for P, K and Mg. In the PC system the average soil P index declined from 3 to 2, the K index was maintained at 2- and the Mg index increased from 3 to 4. Very high rainfall was recorded in 1999 and 2000 and in both systems the soil pH declined during the project from >6.0 to <6.0.
(4) No major weed problems were recorded in either system with the grazing pastures topped during the growing season to prevent the existing dock populations increasing. Few weeds were recorded in the spring barley and triticale cereal crops, irrespective of whether the crops were sown as a monoculture for grain production or undersown with grass/clover mixtures for conservation as arable silage. Rooks proved a problem with barley crops causing a loss of up to 10% of the total grain. This problem was attributed to the challenge of growing cereal crops in an area with >95% grassland and an abundance of woodlands.
(5) In both systems short-term leys of Italian ryegrass/hybrid ryegrass/red clover provided the main forage for conservation. Average forage yields (t DM/ha) from both short and medium-term leys were higher in the PC system than in the SS system, including both the grass and clover components of the mixed sward. Including

herbs in the perennial ryegrass/white clover seed mixtures increased the potential yield of minerals but the herbs were short lived, especially salad burnet and yarrow. The average quality of the herbage for both grazing and conservation was similar in both systems. The quality of the grazed herbage in the systems remained above 74% DOMD during the growing season, with DOMD values of 62.0-66.1 and 60.6-65.4% recorded in the herbage cut for conservation from the perennial ryegrass/white clover and Italian ryegrass/red clover swards, respectively. The crude protein content of the first-cut silage (8.0 to 11.8%) was significantly lower than the values recorded at the subsequent cuts (11.4 to 20.8%) and was attributed to the cool, wet spring weather conditions that led to the slow growth of clover plants within the mixed swards.
(6) In the SS system grain yields (excluding losses due to bird damage) ranged from 2.57-3.38 and 3.17-4.07 t /ha for the spring barley and spring-sown triticale crops, respectively.
(7) Calculation of the crop energy output from the two systems (calculated as Scandinavian Feed Units) showed a higher energy output from the PC system based on an all-forage rotation (8.30 t DM/ha) compared with the output of 7.14 t DM/ha from the forage + cereal crops in the SS system.
(8) Throughout the study the stocking density of the PC system (range 1.62-1.83 LSU/ha) was higher than in the SS system (range 1.14-1.44 LSU/ha). A higher level of concentrates was fed per cow in the PC system than in the SS system (>1.3 v 0.4 t/cow), leading to both increased milk production per cow and per ha (PC – 6,095 & 10,757; SS – 5,276 & 5,968 litres, respectively). However, milk production from forage was significantly higher in the SS system (4,441 v 2,875 litres/cow) due to the more efficient utilisation of feed by cows within the system. However, low milk protein values and high milk fat to protein ratios were recorded during early lactation with some individual cows in the SS system, indicating sub-clinical ketosis due to the feeding of low-energy diets. Compared with the PC system the yield persistency and total milk protein production during the lactation of heifers in the SS system was lower. Cows in the SS system also had lower body condition scores (lower by 0.5). A high proportion of milk samples in both systems had low lactose values and these were correlated with higher milk somatic cell counts, rather than the differences in the energy density of the respective diets.
(9) Feeding a low level of concentrates to the cows in the SS system improved the feed conversion efficiency and led to a higher gross energy utilisation of feed for milk production compared to the efficiency in the PC system. Once the two systems were well established the efficiency of forage utilisation per ha (calculated as GJ of UME/ha for both grazed and conserved forage) was similar in both systems SS – 65.6; PC – 65.1 GJ).
(10) In both systems the margins over concentrates (£/cow & £/ha) declined sharply from spring 2001 onwards following the decline in the price paid for organic milk (SS – £1,335 to 1,129/cow, £2,019 to 1,370/ha; PC - £1,463 to 1,104/cow, £2,780 to 2,464/ha). While margin/cow was not significantly different between the systems the margin/ha was markedly higher in the PC system due to the higher stocking density and increased level of milk production. Compared to the PC the more efficient feed conversion by cows in the SS system resulted in a higher margin over concentrates/litre throughout the project. In the PC system the high price of purchased organic concentrate feeds was maintained throughout the project (>£180/t). However, the estimated cost of home-grown concentrate feeds in the SS system was also high (£200/t).
(11) No major health problems were recorded in either system throughout the project with a relatively low incidence of the main health problems normally associated with many conventional herds (clinical mastitis, lameness and infertility). In both systems the average somatic cell counts in the milk (SS – 267,300; PC – 292,300) were similar to the levels reported in other studies, but higher than the average in UK conventional herds. Sub-clinical rather than environmental mastitis was the main cause of the high somatic cell counts in the milk from some cows in both systems. The average culling rates (SS – 19.5; PC – 17.4%) were similar to the culling rates recorded in other organic herds. The average age of the cows in both systems (<3.0 lactation's) was attributable to both the culling rates and extra heifers entering the herds to increase animal numbers during the establishment of the two systems.
(12) In the PC system the overall pregnancy rate was within the target of 85-90%, however, in the SS system the pregnancy rate declined to <85% following a reduction in the level of concentrates fed per cow and the feeding of diets with a low energy density. In both systems the number of days from calving to conception increased during the project, attributable to the management decision to delay the service date for some cows and change the calving pattern in both systems from all-the-year-round to spring calving. This policy was implemented to maximise the benefits for the cows of grazing high-quality herbage (rather than consuming lower quality conserved forage) during the period of peak milk production.
(13) The Holstein-Friesian cows performed well on the diets fed in the PC system, maintaining adequate body condition scores throughout the different stages of lactation. However, in the SS system while some cows adapted well to the low-concentrate diets others recorded a higher loss of body condition, lower milk persistency during lactation and poorer reproductive performance.

(14) The calves born in each system were reared together before returning to the system in which they were born. Minimal health problems were recorded during the project and satisfactory growth rates achieved prior to the animals calving at a minimum age of 2-years old.
(15) The management of the PC system was easier than in the SS system in relation to the establishment of an all-forage rotation, maintaining a relatively stable stocking density, balancing the rations and avoiding problems associated with low energy diets. The problem of low energy diets that were recorded with some cows in the SS system could only have been avoided if the area allocated to the production of concentrate feeds was significantly increased to allow a higher level of concentrate feeding. This option would result in a sharp decline in the stocking density of the system. Between-season variations in crop yields had a more marked influence on the SS system compared with the PC system. Changes in the standards for organic production and the requirement to include organic seed in the mixtures led to an increase in the calculated forage production costs, particularly for short-term leys.
(16) With the exception of the difficulty of obtaining organic seed for specific grass and clover varieties, high cost of organic concentrate feeds and required changes in the feed storage facilities no major problems were experienced in managing the two systems to meet the standards required for organic production (including responding to the changes in the standards).
(17) In the modelling work fifty-four different strategies for organic dairy production were evaluated. Performance data from three commercial organic dairy farms with different climatic conditions (Devon, Pembrokeshire and Shropshire) and cropping strategies (arable with all home-grown feed, home-grown forage only, home-grown forage + purchased concentrates) and also data from the two Ty Gwyn systems was inputted into three models (SAC Dairy Systems, SAC FeedByte, IRS OrgPlan) to evaluate the potential performance from different organic systems. The results produced a range of different options and rankings in relation to their potential financial performance and use of resources. The results from the data modelling predicted the best financial performance and utilisation of resources would be achieved by the establishment of an arable system on the Pembrokeshire farm. The lowest financial performance was predicted to be from the establishment of purchased concentrate systems on the Shropshire and Pembrokeshire farms, with the poorest utilisation of resource use indicators from both the establishment of a forage-only system on the Shropshire farm and purchased feed systems on both the Shropshire and Pembrokeshire farms. In relation to financial indicators the modelling work showed little difference between the two Ty Gwyn systems.
(18) The financial performance of Ty Gwyn and ten commercial organic dairy farms was monitored during the 1998-2002 period. Of the ten commercial farms, four had been organic for a number of years, three were recently converted and three were in conversion. The net farm income of the Ty Gwyn SS system increased from 1998/99 to 1999/00 to a peak of £25,453 but then declined sharply following a fall in the price paid for organic milk to a loss of -£14,269 in 2001/02. In the Ty Gwyn PC system the net farm income increased to £24,122 in 2000/01 but then fell sharply to a loss of -£4,825 in 2001/02. The peak net farm incomes on the commercial farms were recorded in the 1999/00 period, with either a small loss (<-£50/ha) recorded on the well established farms or a small profit (<£50/ha) on the recently converted farms in 2001/02.

Scientific report (maximum 20 sides A4)

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THE PERFORMANCE OF TWO SYSTEMS OF ORGANIC MILK PRODUCTION

1. Introduction

Two systems of organic milk production (SS – self sufficiency; PC – purchased concentrates) were established on the IGER Ty Gwyn organic dairy farm during Year 1 of the project (01/10/1998-30/09/2002). The total land area was divided into two separate areas on the basis of the soil P and K index, cropping type and position in the rotation to provide a balance between the systems in average soil fertility and crop type and yield. To allow for the growing of concentrates in the SS system the land area allocation was 51.01 compared with 43.46 in the PC system, with 20% of the land in both systems maintained as permanent pasture. The Holstein-Friesian dairy cows were allocated to the two systems using the following criteria: age, origin, milk yield, milk quality, reproductive status and health status. With the exception of lime (which was applied when fields were ploughed) no permitted fertilisers were purchased, with the strategic use of slurry, farmyard manure and N-fixation by legumes used to maintain soil fertility within the two systems.

2. Soil indices

All field in the two systems were sampled in February 1998, 2000 and 2002. Samples were taken by auger to provide two bulked samples for each field. Each bulk sample consisted of samples from 25 evenly-spaced positions taken in a 'W' pattern that was representative of the whole field area. Results reported here are the means of the two samples for each field. To minimise the effects of cultivation and type of cropping in different years, soils were sampled to 20 cm to represent the full depth of the plough layer, rather than sampling to 7.5 cm for grassland or 15 cm for arable land as normally recommended for advisory purposes (MAFF, 1985). Samples were air dried, crushed and sieved and the <2mm fraction analysed using standard methods (MAFF, 1985). Phosphorus was extracted from soil samples with sodium bicarbonate solution at pH 8.5. Potassium and magnesium were extracted with ammonium nitrate solution. Soil pH was measured in a freshly stirred suspension of soil in water, using a glass electrode.

During the project the average soil pH of the fields in the SS system declined from 5.9 to 5.6 and from 6.1 to 5.6 in the PC system. In 2002, soil pH was less than 5.5 in almost half the fields. Mean values of soil pH for red clover and white clover field mixtures in the SS and PC systems that were sampled in 1998, 2000 and 2002 are summarised in Table 1. The results from the samples taken in 1998 showed the average soil pH of the red clover fields to be greater than 6.0. In 2000 and 2002 the values ranged from 5.7 to 5.9 in both systems. In 1998 the values for soil pH in the fields with white clover/perennial ryegrass mixtures were 5.9 and 6.1 for the SS and PC systems, respectively. In 2000 and 2002 the means were lower and with the exception of one field in the SS system there were no fields with a pH above 6.0. The soil pH of fields with white clover mixtures in the PC system were generally higher than the soil pH of fields in the SS system and the DM yields of herbage were also higher in the PC system.

Table 1. Mean pH of soils in 1998, 2000 and 2001 for different sward types and total lime required to adjust soils to pH 6.0.

Sward type:		1998	2000	2002	Lime requirement (t/ha)
Red clover/ryegrass	SS	6.5	5.9	5.7	2.0
	PC	6.4	5.8	5.7	2.0
White clover/ryegrass	SS	5.9	5.1	5.3	4.3
	PC	6.1	5.6	5.6	2.6

The results show that in both systems the soil pH of fields with white clover/ryegrass mixtures had fallen between 1998 and 2002 following periods of very high rainfall in the 1999/2000 winter and autumn of

2000. Clover in particular has a high requirement for lime and thrives between pH 5.5 and 6.5. In considering the amount of lime required to bring the fields up to pH of 6.0 it would need on average 2.0 and 4.3 (SS system) and 2.0 and 2.6 t/ha (PC system) of lime on the red and white clover mixtures, respectively.

Table 4.1.2 shows the number of fields within each system, grouped according to the appropriate index for extractable P, K and Mg. To avoid major fluctuation in the soil indices of the individual fields the management strategy for the utilisation of on-farm slurry and farmyard manure was to give priority to silage fields and ensure fields with low P and K status received a minimum of 1-2 applications per annum. Except for two fields in 2000, all fields maintained P and K indices of between 1 and 4. Indices for Mg were slightly higher, between 3 and 6. No major changes were recorded in the average soil P index for fields in the SS system, which remained at Index 2 in each year. The average P index for the PC system declined from Index 3 in 1998 to Index 2 in 2000 and 2002. In both systems the average soil K content was equivalent to Index 2- in each year of the project. In both systems the average Mg index increased from 3 in 1998 to 4 in 2002.

Table 4.1.2. Soil P, K and Mg indices for 1998-2002: the number of fields in the SS and PC systems falling within each index category.

	SS system						PC system					
Extractable phosphorus												
Index:	0	1	2	3	4		0	1	2	3	4	
1998	0	0	11	3	0		0	1	6	3	2	
2000	0	4	9	1	0		0	7	3	1	1	
2002	0	3	5	6	0		0	4	5	2	1	
Extractable potassium												
Index:	0	1	2-	2+	3	4	0	1	2-	2+	3	4
1998	0	7	5	2	0	0	0	4	5	1	2	0
2000	2	6	5	1	0	0	0	10	1	1	0	0
2002	0	3	3	7	1	0	0	1	5	4	2	0
Extractable magnesium												
Index:	1	2	3	4	5	6	1	2	3	4	5	6
1998	0	0	11	2	1	0	0	0	10	2	0	0
2000	0	0	6	7	1	0	0	0	6	4	1	1
2002	0	0	7	7	0	0	0	0	6	4	2	0

Unlike conventional systems where both purchased fertilisers and on-farm manure sources are available for maintaining soil nutrient contents, organic farms are dependent on maintaining legume production and effectively utilising the available on-farm manure sources. The priority in both of the systems at Ty Gwyn was to apply the slurry on fields with the lowest P and K levels. With the exception of lime that was normally only applied when fields were ploughed, no approved fertilisers were purchased and applied in either system.

3. Crop production

(a) Methodology

The main objective was to establish two different crop rotations for the SS and PC systems and to record the production from different crops within the rotations, the clover content of the grass/clover swards and sward quality throughout the growing season during the project on all grazing and silage fields. The strategy in both of the rotations was to produce sufficient forage annually for both grazing and conservation and also ensure a reserve stock of silage was maintained as an insurance against forage shortages in dry summers and long winters. A specific objective was to study different crops within the rotations with special reference to changes in soil P and K status of the two contrasting systems. To achieve a balance between the two systems at the start of the project all the fields were allocated to each system with the objective of achieving a balance between the systems in cropping type, position in the rotation and P and K status. Two separate crop rotations were established on the land areas allocated to the two dairy herds (SS – 41.6 ha; PC – 34 ha). A separate area of land (18.9 ha), including the main area of permanent pasture, was allocated to the rearing of the replacement stock for the two systems.

In the SS system different varieties of spring barley and triticale were grown for grain and straw production. To increase the winter protein supply in the diet of cows in the SS system 3 ha of pure red clover was sown in April 2001 at a seed rate 12 kg/ha. In the PC system the all-forage rotation was based primarily on grass/clover swards. Spring barley was also used as a cover crop for establishing grass/clover swards and conserved as whole-crop silage. In both systems Italian-hybrid ryegrass/red clover swards provided the main forage for conservation as silage and feeding during the winter period. Perennial ryegrass/white clover swards were used for both grazing and conservation. Following the improved herbage quality reported with high sugar grasses in trials at Lodge farm, the variety AberDart was included in the seed mixtures that were sown in the rotations of both systems at Ty Gwyn.

A key management priority in both systems was to maintain adequate control of weeds in both the cereal and grass-based swards, particularly docks. Minimal weed problems have been recorded in the cereal crops grown for both grain (SS system) and whole-crop silage (PC system), irrespective of whether the cereal crops were sown as monocultures or undersown with grass/clover mixtures 10-14 days after the cereal crops were sown. Since the start of the conversion of the farm in 1992 the overall dock populations at Ty Gwyn have neither increased or decreased but during the rotation the dock populations have been higher in short-term leys where the swards are more open and higher inputs of slurry have been applied. In the medium-term leys of perennial ryegrass and white clover and also in the permanent pastures the strategy has been to use higher seed rates to establish dense swards that prevent dock populations increasing, with the swards topped during the grazing season and dock plants defoliated by sheep during the November-December period.

All grazing fields were monitored for herbage accumulation under exclusion cages, each cage measuring 1.5 x 0.9 x 0.4 m high. Five cages were used per field. Swards within the cages were sampled at intervals of 4-5 weeks and after each sampling the cages were repositioned on a rotational basis to avoid repeated sampling of the same area. The yield of herbage from all silage fields was measured from six random areas per field immediately prior to cutting the fields for silage. All grazing and silage fields were sampled at a cutting height of 5-6 cm with the reciprocating 60cm wide blade of a petrol driven hand mower. Fresh herbage was weighed and two sub-samples were taken, one for dry matter (DM) determinations and the second for botanical analyses with the sample separated by hand to calculate the proportions of grass and clover in the sample. Both samples were then dried for 16 hours in an Unitherm oven at 80 ^{0}C and weighed. The DM yield of clover was calculated from the separated botanical sample. The samples of herbage harvested in the field from both the grazed and cut fields were milled and analysed by the IGER Analytical Chemistry group for crude protein (CP) contents and in vitro (two-stage) digestibility. Every trailer load of grass cut for conservation as silage was weighed and sampled for dry matter content before the crop was ensiled. Three silage clamps were allocated for each of the two systems. In both systems additional herbage was conserved as silage in big bales.

(b) Results

Comparison of the yields under different field management for the two systems is shown in Table 2. On areas conserved primarily for silage the total mean yields of DM produced from re-seeded perennial/white clover swards in the PC system were consistently higher than the yields in the SS system. The results from measuring the annual herbage production showed that production in the PC system was greater than the corresponding yield in the SS system in every spring, the differences being particularly marked in 2000. In the conversion period and early stages of organic production at Ty Gwyn, Italian Ryegrass/red clover leys made a major contribution to the total herbage production, contributing more than 50% of the herbage required for conservation and feeding during the winter period. However, quality is often lacking in mid-season when leys are based on diploid Italian ryegrass varieties. Developments in the IGER breeding programme have led to the availability of tetraploid hybrid ryegrass (e.g. AberExcel and AberLinnet) that are more palatable and digestible and these hybrids have now been included in the seed mixtures for short-term leys based on red clover.

Herbage production

As shown in Table 2 the overall average yield of herbage was slightly higher in the PC system (9.75 v 9.30 t DM/ha). However, the yield differences between the two systems decreased as the project progressed and the reliance on 100% home-grown feed in the SS system from October 1999 onwards does not appear to date to have yet affected total herbage yields. The highest yields of herbage were recorded in both systems from the short-term leys based on red clover (Table 2) and were similar to the yields from red clover leys reported by McBratney (1984). The range in the yields from the individual fields reflects the differences in the age of the swards with the lowest yields recorded in the year of establishment. Overall the average yields reported in both systems from the three management systems (grazing, cut + grazed, cut only) were not significantly different from those recorded at Ty Gwyn prior to the establishment of the two systems. Other factors that influenced the yield from the individual fields were soil type and in some grazing fields the application of on-farm manure sources to improve the level of production. The establishment of a pure red clover sward in the SS system to reduce the problem of low protein in the winter diets led to a high yield (13.44 t DM /ha) in the first full year of production and the production of a silage with a crude protein content of 19.5 %.

In 3 of the 4 years during which the yields were measured the total quantity of herbage produced for grazing and conservation was higher in the PC system, with the higher yields in 2002 attributable to the high yields recorded from the pure red clover sward. Although the differences between the systems in the average yields were not large the requirement in the PC system for less forage in the diets (due to the feeding of a higher level of concentrates) led to the stocking densities on the forage-only areas in 2001 and 2002 being higher in the PC system (1.62 & 1.68) compared with the SS system (1.48 & 1.34 LSU/ha).

Table 2. Annual yield of herbage harvested per field at Ty Gwyn (t DM/ha)

Field management	1999	2000	2001	2002	Mean
SS system					
Grazed only: average	7.76	9.53	7.95	9.49	8.68
lowest	7.24	8.27	6.51	8.66	
highest	8.17	10.60	9.00	10.22	
Grazed/cut (white clover mix)					
Average	9.13	8.88	7.89	8.89	8.98
lowest	7.94	7.65	6.45	7.38	
highest	10.05	10.31	9.40	10.53	
Cut only (red clover mix)					
Average	9.11	11.35	9.91	10.62	10.25
lowest	7.18	10.59	9.74	10.22	
highest	10.73	12.12	10.01	11.03	
Cut only (pure red clover)			7.44	13.44	10.44
Overall mean (all crops)	8.67	9.92	8.30	10.89	9.30
PC system					
Grazed only: average	8.29	9.07	8.72	9.16	8.81
lowest	7.47	7.58	7.41	8.26	
highest	8.95	12.67	11.84	12.25	
Grazed/cut (white clover mix)					
Average	10.53	10.85	9.2	9.95	10.13
lowest	8.42	9.75	7.87	8.65	
highest	13.54	12.16	11.63	10.89	
Cut only (red clover mix)					
Average	10.23	10.76	8.53	11.67	10.30
lowest	7.18	10.48	7.90	11.17	
highest	10.73	11.04	9.69	12.17	
Overall mean (all crops)	9.68	10.23	8.81	10.26	9.75

The seasonal growth pattern of the fields that were either conserved or grazed is shown in Table 3. The highest yields were recorded at the spring sampling in the grazed fields and at cut 1 in the fields cut for silage. The highest yields in early season were recorded in 2000 despite the average temperatures in March and April being lower than in some other years.

Table 3. Seasonal production in the grazed and conserved swards (t DM/ha)

CUT:	SS system				PC system			
	Cut 1	Cut 2	Cut 3	Total	Cut 1	Cut 2	Cut 3	Total
1999	3.34	2.50	3.17	9.01	3.97	2.60	3.79	10.36
2000	4.72	2.49	2.52	9.73	5.85	2.09	2.28	10.22
2001	3.62	2.42	2.70	8.74	3.63	2.75	2.34	8.72
2002	4.00	3.49	2.55	10.04	4.56	3.20	2.61	10.37
Mean	3.92	2.73	2.73	9.41	4.50	2.66	2.76	9.92
GRAZ-ED	Spring	Summer	Autumn	Total	Spring	Summer	Autumn	Total
1999	3.14	2.91	1.73	7.78	3.39	3.48	1.88	8.74
2000	4.35	3.21	1.69	9.25	4.13	3.51	2.02	9.66
2001	3.46	2.20	1.90	7.55	3.61	2.53	1.94	8.09
2002	3.42	3.23	2.31	8.96	3.63	3.47	2.08	9.18
Mean	3.59	2.89	1.91	8.39	3.69	3.25	1.98	8.92

The average clover content in the swards was lower and the grass yield higher in the PC system. This pattern was recorded in both the red clover and white-clover re-seeds. Although the clover content of the permanent pastures was higher in the PC system the grass yield was lower, however, the average is based on only a small number of observations. The trend for a higher clover content in the PC system was recorded in the grazed, cut + grazed and cut only swards. The lower clover content in the PC system did not depress grass yields and may be attributable to the higher stocking density (e.g. grazing fields) and importation of extra nutrients (via purchased concentrate feeds) in the system.

Although the quantity of surplus N in the whole-farm system is generally lower on organic farms compared with conventional farms (Halberg *et al*, 1995; Kristensen & Kristensen, 1992), N-utilisation by the dairy cow may be similar. Samples of grass and white clover plants taken throughout the growing season from mixed grass/clover swards at Ty Gwyn, in both grazing fields and simulated-grazing plots, has shown an excess of protein for the dairy herds from early July onwards (Weller & Cooper, 2001). The protein content of both the grass and white clover increases as the grazing season progresses, leading to an inefficient use of protein unless the energy density of the diet can be increased. In the PC system, where the level of concentrate inputs to the dairy herd was higher than in the SS system, there was the potential to feed more concentrates and improve the energy:protein ratio. However, the all-the-year-round calving pattern limited the opportunity to improve the energy:protein ratio as the level of concentrate inputs was influenced by both the calving date and milk yield of the individual cow. Following the successful use of high-sugar perennial ryegrasses at IGER in improving the efficiency of N-utilisation in conventional systems (Moorby, 2001), the IGER-bred high sugar variety AberDart was included in the seed mixtures for the medium-term leys in both systems.

The strategy for providing extra minerals for the cows in each system was based on the purchase and feeding of seaweed meal and the inclusion of herbs in the seed mixtures based on perennial ryegrass/white clover. Poor establishment and persistency under the wetter climatic conditions of Ty Gwyn were recorded with salad burnet and yarrow. Better establishment was achieved with chicory and ribgrass plantain, with both species persisting in the swards for at least two growing seasons. Herb strips within grass/clover swards were considered as an alternative option but this idea was rejected due to concern about docks dominating the strips, leading to suppressed herb growth and increased weed problems in the succeeding crop.

Herbage quality

Table 4. Mean DMD% and DOMD% of the herbage

	SS system				PC system			
Field management	1999	2000	2001	Mean	1999	2000	2001	Mean
Grazed only (DMD%):								
Spring	76.5	75.5	76.1	76.0	75.9	76.4	75.2	75.8
Summer		73.9	75.2	74.6	75.4	74.8	76.2	75.5
Autumn	74.4	75.5	75.4	75.1	74.3	75.9	75.9	75.4
White clover standing crop								
(DOMD%) Cut 1	61.2	62.7	64.4	62.8	61.6	59.7	64.8	62.0
Cut 2	63.3	*	66.3	64.8	62.0	65.7	68.2	65.3
Cut 3	63.1	*	*		63.7	69.1	65.6	66.1
Red clover standing crop								
(DOMD%): Cut 1	61.5	58.6	61.6	60.6	61.1	59.9	62.5	61.2
Cut 2	60.5	63.9	63.0	62.5	59.0	61.7	61.3	60.7
Cut 3	60.9	65.9	69.4	65.4	58.4	63.2	63.2	61.6

* No silage cut taken

In both systems the crops for conserving as silage were treated with an inoculant prior to ensiling and silage analyses during the project showed low ammonia-N values, with minimal wastage on both the surface and sides of the silage clamps following the correct sealing of the clamps. In both systems the quality of the silages were relatively low, reflecting the stage of maturity of the crops conserved (Table 4) and the need to maximise the annual quantity of silage that is required for feeding during the 200-day winter period. Differences between the systems in mean herbage quality from grazed-only fields and white/red clover silage fields were generally small. The results show only small differences between the harvest dates in digestibility. Changes in the crude protein content of the different swards within the two systems are shown in Table 5.

Table 5. Crude protein concentrations of herbage and silage samples (% DM)

	SS system				PC system			
Field management	1999	2000	2001	Mean	1999	2000	2001	Mean
Grazed only:								
Spring	15.6	16.9	15.2	15.9	15.9	17.1	15.9	16.2
Summer	20.3	20.4	20.5	20.4	19.1	20.8	21.6	20.5
Autumn	24.9	23.6	25.7	24.7	23.6	23.9	25.6	24.3
White clover silage:								
Cut 1	11.8	9.9	11.0	10.9	11.8	9.6	9.9	9.1
Cut 2	11.4	*	16.7	14.0	11.34	17.7	12.9	14.0
Cut 3	18.3	*	*		16.6	18.8	15.8	17.1
Red clover silage:								
Cut 1	10.3	9.3	10.2	9.9	9.3	8.0	10.1	9.1
Cut 2	12.5	14.2	14.8	13.8	12.0	14.3	13.2	13.2
Cut 3	15.5	16.9	20.8	17.7	14.6	16.2	17.8	16.2

Successive springs of cool and wet weather delayed herbage growth and reduced the forage yield of first cut silage, resulting in a low clover content and silage with a low crude protein content. The relatively low crude protein levels at first cut may be partly due to cold temperatures experienced in spring/early summer, which may have reduced the rate of both clover growth and N-fixation.

Previous results (Holmes, 1980) showed that the D-value of perennial ryegrass during the growing season declined at 3.5 units per week compared with a decline of only 0.8 units per week in white clover. Red clover commences growth later in the spring than grass and initially has a lower D-value. The rate of decline in the D-value of the red clover is slower than in the grass but faster than the decline in the D-value of the white clover. In the two systems at Ty Gwyn these differences between red and white clover contributed to the small differences in the digestibility values of the two types of silages. Both the high D-value and proportion of white clover in the swards throughout the growing season also contributed to the high D-values of the grazing swards in both systems, with the swards maintained with a high leaf:stem ratio throughout the grazing season.

The main influence of the companion grasses occurred at the first cut in each year when clover was least vigorous, with the lowest crude protein concentrations in the spring for both the grazed and first-cut silage fields. Differences between the two systems were generally small. From previous results at Ty Gwyn the average level of production that can be achieved from short-term leys is higher than the yield from either medium-term leys or permanent pastures (DEFRA Project OF0113). However, with the change in standards for organic production and a requirement to use only organic seed from 2004 onwards the benefits of the higher productivity of the short-term leys may be balanced by the higher establishment costs. The cost of herbage production for different swards within the two systems was estimated in 2001 (Table 6) using the establishment and maintenance costs from the Farm Management Pocketbook (Nix, 2000) and Organic Farm Management Handbook (Lampkin & Measures, 2001) for the calculations. The price of organic cereal grains for feeding have remained relatively constant at three times the price of conventional cereal grains and in the calculations of the cost of grass/clover leys the price for organic seed has been included at three times the cost of conventional seed. A number of estimates from members of the seed trade (personal communications) have suggested the future price of organic seed will range from between 1.5 and 7 times the price of conventional seed. The average yields are based on the yields recorded for the individual swards during the 1996-98 period, including the yield of whole-crop barley during the year of establishment for the Italian ryegrass/red clover ley. The increased cultivation costs associated with the short-term leys of Italian ryegrass/red clover (including the cost of undersowing with spring barley) led to an estimated 16.6 and 10.7% higher cost per tonne of forage DM when compared with the permanent pastures and re-seeded perennial ryegrass/white clover swards. Evaluation of the strategy for crop production within the PC system showed a relatively high cost of forage production per tonne of DM when the increased production costs of the short-term leys are calculated. For these types of systems the option of changing to the production of forage from an all-grassland system based on long-term leys may significantly reduce costs without a marked affect on annual forage yields as the periods of low productivity during the frequent establishment of crops within a rotation will be avoided.

Table 6. Estimated cost of herbage production for three sward types.

1. Estimated costs for average yielding swards	Permanent pasture	5-year re-seeded perennial ryegrass/white clover ley	3-year Italian ryegrass/red clover ley undersown with Spring barley
Primary management	Grazing	Grazing	Conservation
Production costs (£/ha)	415.7	496.7	588.5
Average yield (t DM/ha)	8.53	9.68	10.36
Cost/ tonne DM (£)	48.7	51.3	56.8
Energy cost (p/MJ)	0.46	0.49	0.54

Grain production

Spring barley and triticale were the cereals selected for growing as either grain crops (SS system) or for whole-crop silage. A major problem at Ty Gwyn is establishing and harvesting cereal crops that are both suitable for the climatic conditions and less likely to suffer from major losses due to late maturity or bird damage. Oats was considered as an alternative crop for grain production, however, when grown in plots at Ty Gwyn oats suffered severe losses due to rooks during the period of establishment. Excessive rainfall in late summer of 1999 made cereals harvesting difficult. Following combining a total of 23.6 and 26.4 tonnes of grain was available for feeding to the cows in the SS system during the 1999/2000 and 2000/2001 periods, respectively, from the barley (varieties: Chariot, Dandy and Riviera) and triticale crops (Purdey, Taurus). In 2001, three different varieties of triticale (Fedelio, Purdey & Taurus) and one variety of spring barley (Hart) were sown. Due to differences in maturity date only one variety of triticale was harvested as grain with the other two varieties conserved as whole-crop silage. The grain yields from the combined cereal crops were 3.23 t of triticale and 9.25 t of spring barley, providing a total of 12.48 t for feeding to the cows in the SS system cows during the 2001/2002 period.

Overall the grain yields from both the spring barley and triticale crops in the SS system were lower than predicted in the Development Plan, irrespective of whether the crops were grown as a monoculture or undersown, leading to less grain being available for feeding to the SS dairy herd. However, as the majority of crops were spring sown the grain yields were satisfactory when compared with the yields reported from winter-sown organic cereal crops (Welsh, 2001) which generally produce 15-30% more grain than spring-sown crops (Nix, 1996; Wibberley, 1989). However, the yields recorded at Ty Gwyn were significantly lower than the predicted yields of 4.4-5.0 t/ha for spring-sown cereals grown in conventional systems (Wibberley, 1989).

Energy production from the different crops

Calculation of the Scandinavian Feed Units (SFU) in other EU countries from crops within both conventional and organic systems has proved an effective method of comparing the output from both individual farms and different types of crops within an individual farm in relation to both the level of energy production and contribution to the total energy requirements of the livestock enterprise on the farm (Berg & Thuen, 1991; Sundstol, 1993). In the current project the recorded yields and chemical analyses from all home-grown feeds produced within the two systems (herbage types, different silages, grain and straw) have been used to calculate the SFU using an energy conversion factor of 12.9 MJ per unit of SFU. As shown in Table 7 the inclusion of cereal crops for grain production in the SS system reduced the annual energy output (SFU t/ha) compared with the PC system, with the differences increasing to 1.29t SFU/ha in 2001. It is important to note that the higher crop energy production from the all forage rotation in the PC system will be influenced by the more favourable growing conditions for grass-based swards in the western areas of the UK. Organic farms further east in the UK, where cereal grain yields are higher and yields from grass-based crops lower, may have the potential to produce a higher crop energy output from SS rather than PC systems of organic production. In both systems the energy production in 2001 was significantly lower than in 1999.

Table 7. Energy production calculated as Scandinavian Feed Units (SFU t/ha)

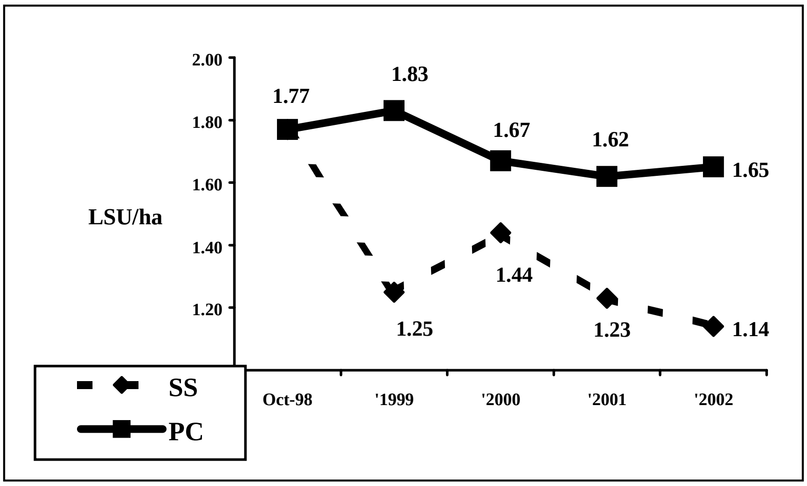
	SS			PC		
	1999	2000	2001	1999	2000	2001
Cow + Youngstock area	8.07	7.65	6.39	9.28	8.37	7.41
Cow area only	7.45	7.67	6.31	8.72	8.59	7.60

4. Herd performance

Stocking densities

The sharp increase in cow numbers in the SS system during 2000 significantly increased the stocking density to 1.44 LSU (Livestock Units/ha), leading to a high efficiency of forage utilisation but increased pressure on forage stocks. For some cows the higher stocking density and increased competition during grazing led to more post-calving health problems, lower milk persistency, increased loss of body condition, reduced milk quality and lower reproductive performance. To reduce the pressure on forage supplies the stocking density was reduced to 1.23 LSU/ha in the 2000/01 period.

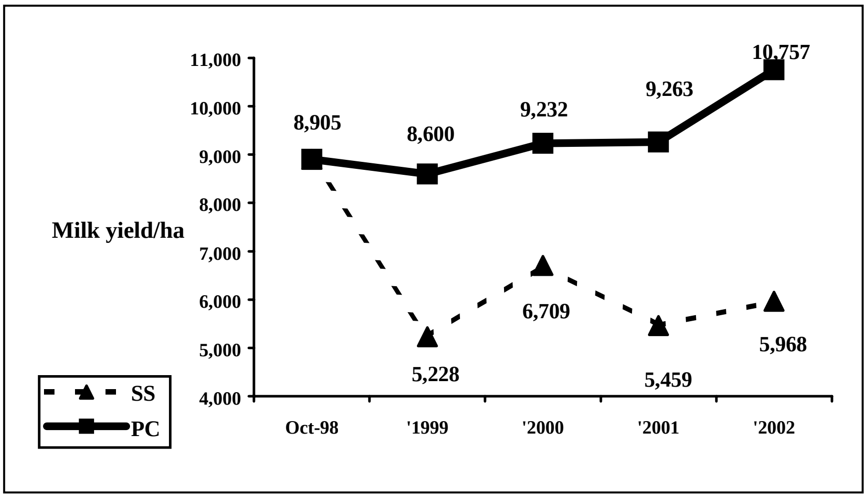
Fig 1. Annual changes in the stocking density of the two systems (LSU/ha).



As shown in Figure 1 there was a further decline in the stocking density during the 2001/02 period. In other self sufficient systems, where either different cropping strategies were implemented (including allocating a greater proportion of the total land area to the production of concentrate feeds and high energy crops) or the systems were managed under different soil types and climatic conditions, the stocking density was <1.10 LSU/ha and similar to the SS system at Ty Gwyn in the 2001/02 period. For some farms the average stocking density has been reported as low as 0.8 LSU/ha on some individual farms (Halberg & Kristensen, 1997; Kristensen & Kristensen, 1998; Kristensen & Pedersen, 2001).

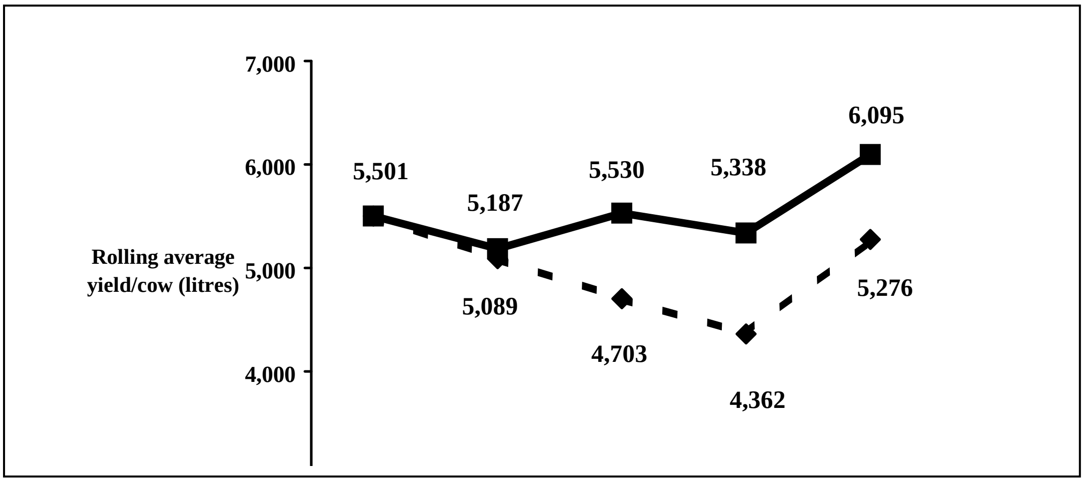
Herd performance

Fig 2. The annual milk production per hectare (litres)



The total production of milk per hectare (litres) is shown in Figure 2 with the figures calculated from the total production/annum divided by the land area for the dairy herds, including both the areas allocated for forage and concentrate production in the SS system. Milk production per hectare increased in the PC system during the project and was significantly higher than the production from the SS system.

Fig 3. The annual rolling average milk production per cow (litres**)**

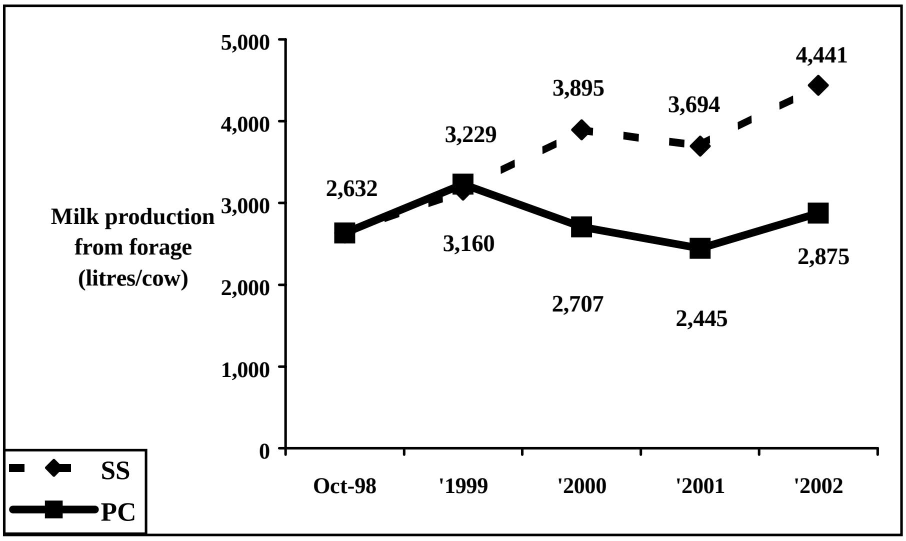


In Figure 3 the annual rolling average milk yield/cow has been calculated by dividing the total annual milk production by the average number of cows (both lactating and dry cows) in the herd during the year. In the SS system reducing the quantity of concentrates fed per cow led to both a lower rolling average yield and total milk yield per cow (Figures 3). Increased animal numbers and a higher stocking density in the 1999/00 period increased grazing pressure and also contributed to a higher negative energy balance, reducing the milk yields of the cows within the system. In the PC system during the project no major changes occurred in either the rolling averages or annual milk yield per cow until the 2001/02 period. In both systems the recorded milk yields per cow would have been influenced by the average herd age, with the majority of cows culled before reaching the age when peak production is achieved.

Reducing the level of concentrates fed in the SS system improved the production of milk from forage/cow to a peak of 4,441 (rolling average) as shown in Figure 4, significantly higher than the output recorded from either the PC system or many other commercial organic dairy herds (OMSCO, 2001). In the PC system although the total milk production per cow, milk persistency and maintenance of body condition during lactation were satisfactory the milk production from forage declined to below 3,000 litres/cow, similar to the levels recorded in UK conventional herds (Promar, 2002). The contribution of energy from home-grown forage to milk production was markedly lower in the PC system compared with the SS system.

Forage quality is an important factor in organic dairy production as the price of organic concentrate feeds is high. The fall in the organic milk premium from 2001 onwards increased the importance of aiming to improve forage quality and the efficiency of forage utilisation, although ensuring sufficient quantities of fresh and conserved forages are always available will remain a primary objective for organic dairy systems. The recent introduction of high-sugar grasses into the PC system will potentially increase the energy supply in the forage grown for grazing and conservation, leading to improved milk production from forage. In the SS system the introduction of high-energy crops into the rotation will have the potential to reduce the problem of negative energy balance in early lactation and improve both milk persistency and total yield.

Fig 4. The annual rolling average yield of milk from forage (litres/cow)



No major differences were recorded between the two systems in either milk fat or protein content. However, the figures in the table are the annual averages recorded from the monthly samples taken by NMR and they do not reflect either the difference between the individual cows and the influence of the stage of lactation. The results from these monthly milk samples showed that some cows in both systems had milk protein values below 3.0% in early lactation. In both systems changes in the feed of the herds from silage-based to higher quality herbage-based diets also affected milk quality, leading to significantly higher milk protein contents in the milk. Additional milk samples were taken at 14-day intervals from cows and heifers in both systems during early lactation. The results showed the low energy diets in the SS system reduced protein content and increased the fat to protein ratio of the milk from heifers within the system compared to those in the PC system. However, no differences were recorded between the two systems in either the protein content or fat to protein ratio of milk from multi-parous cows. The higher proportion of milk samples with a milk fat to protein ratio of 1.4 or > from cows in the SS system compared with those in the PC system showed a higher energy deficit in the diets. The results from other studies show that these high fat to protein ratios indicate energy-deficient diets with the cows suffering from sub-clinical ketosis (Grieve *et al*, 1986; Duffield *et al*, 1997; Heur *et al*, 2000).

Milk lactose has been found to be a relatively stable component of cow's milk in conventional systems (National Dairy Council, 1997), with changes only occurring when either diets are low in energy (Gordon & Forbes, 1971; Sutton *et al*, 1985) or milk has a higher somatic cell count (Heeschen, 1975). Both of these factors are important in organic dairy production and any changes in lactose content will affect the processing quality of the milk. Changes in lactose content have also been found to be a useful indicator of both clinical and sub-clinical mastitis (Traore *et al*, 1979). As differences were found between the two systems in both the protein content and fat to protein ratio of the milk the lactose content was also determined in 530 samples from individual cows within the two systems. A high proportion of the samples (n=218) had lactose values of <4.5%, with the values ranging from 3.15-4.97 (SS system) and from 3.50-5.01 (PC system). The proportion of milk samples with lactose values of <4.5, 4.5-4.7 and >4.7% was 37.5, 45.5 and 17.0% in the SS system and 44.8, 36.8 and 18.4% in the PC system. Low lactose values were correlated with higher somatic cell counts and these results suggest that in the current project cell counts, rather than the differences between the systems in dietary energy, influenced lactose content.

In the SS system the DEFRA Steering Committee suggested only home-grown concentrate feeds were fed to the dairy herd unless welfare problems occurred and extra purchased concentrates were required to overcome the problem. From October 1999 onwards home-grown cereal grains (spring barley and triticale) were available for feeding to the dairy cows. The quantities of grain available for feeding each year was dependent on both the number of cows in the herd and total quantity of grain harvested. The overall yields of grain harvested were lower than expected and led to the quantity of grain fed per cow declining to <0.5 t/cow in the 1999-2001 period (Table 8). In 2001-2002, following problems in the ripening of the cereal crops, only 12.48 t of grain (<0.3 t/cow) was harvested and the decision was made to purchase an additional 12 tonnes of organic wheat grain. Although this decision reduced the annual proportion of home-grown feed, priority was given to avoiding an increased negative energy balance in the rations and potential health and welfare problems, including post-calving problems and an excessive loss of body condition during early lactation.

While protein contents of the grazed herbage were adequate during the grazing season for both herds, during the winter periods when conserved forages were fed the protein content of the diets for the SS cows was below 14%, attributable to low protein contents in both the first-cut silage and cereal grains. To overcome the problem of low protein in the diets a pure sward of red clover was established, leading to the production of a forage with a protein content of 19.5%.

Table 8. The quantity of concentrates fed in both systems.

	Concentrates fed:	Tonnes/cow/year)	Kg/litre of milk
SS system	1998/1999	0.832	0.16
	1999/2000	0.403	0.09
	2000/2001	0.347	0.08
	2001/2002	0.414	0.08
PC system	1998/1999	1.085	0.21
	1999/2000	1.319*	0.24
	2000/2001	1.415	0.27
	2001/2002	1.557	0.26

* including 0.2 t/cow of brewers grains

Efficiency of feed utilisation

Table 9. Gross energy efficiency: the energy contribution for milk production from home-grown and purchased feeds (MJ of milk per MJ of feed).

April-March period:	1999-2000	2000-2001	2001-2002
SS system			
Milk produced from:			
Total home-grown feed	0.26*	0.30**	0.37
Total home-grown feed minus estimated losses	0.32	0.36	0.46
All feed (both home-grown and purchased)	0.32	0.33	0.37
PC system			
Milk produced from:			
Total home-grown feed	0.25	0.13***	0.23
Total home-grown feed minus estimated losses	0.32	0.16	0.29
All feed (both home-grown and purchased)	0.37	0.34	0.29

* A lower output than in successive years as home-grown cereal grains were only available for feeding in the final 5 months of the year

** The output from home-grown feeds was reduced by the feeding of 22.5 tonnes of high-energy dried lucerne

*** A lower output due to the purchase of Brewers grains

The production of milk from different feed energy sources (Table 9) has been calculated to show the differences between the systems in the gross energy efficiency for milk production from both home-grown and purchased feeds during the project. The output of milk from home-grown feed in the two systems was similar in the 1999/00 period as home-grown cereal grains in the SS system were not available for feeding until the final 5 months of the year. In the SS system during the 2000/01 and 2001/02 periods the production of home-grown cereals markedly increased the output of milk per kg of home-grown feed compared with the output from cows in the PC system (also shown by the production of milk from forage). Published results from conventional dairy herds showed a gross energy efficiency range for the diets fed of 0.38 to 0.42 (low forage diets) and from 0.37 to 0.44 (high-forage diets) MJ of milk/MJ of feed fed (Simm & Veerkamp, 1996). However, a number of trials have shown that losses occur during the grazing and conservation of herbage and other crops, leading to significant differences between the total forage produced within a livestock system and the quantity that is actually fed to the livestock. Therefore additional calculated values have been included in the table that assume an average loss of 20% from the total forage produced and 5% grain losses. In the SS system the purchase of high energy dried lucerne in 2000/01, due to a shortage of forage, sharply reduced the milk output from home-grown feed during the year. In the PC system the purchase and feeding of brewers grains in 2000/01 provided extra feed during the period of lower herbage growth but also sharply reduced the annual output of milk from home-grown forage.

Until the end of 2001 the average annual price of the milk sold from the two systems was similar to the price of 29.2 p/litre that was paid at the start of the project in October 1998. However, the price fell sharply from 2001 onwards leading to an average price in the 2001/2002 period of 22.96 p/litre. Peak margin over purchased feed was recorded in both systems during the 1999/00 period. Although margins over purchased feed /cow and /ha were higher in the PC system the margin over purchased feed per litre was higher in the SS system, (Table 10), attributable to the higher efficiency of milk production from forage. As the level of concentrates fed in the SS system decreased the margin per litre of milk increased until the sharp fall in the milk price during the 2000/01 period.

Table10. Margins over purchased concentrate feed

Margins over concentrate costs		1999	2000	2001	2002
Margin/cow (£)	SS	1,330	1,335	1,209	1,129
	PC	1,331	1,463	1,292	1,104
Margin/ha (£)	SS	1,515	2,019	1,600	1,370
	PC	2,447	2,780	2,691	2,464
Margin/litre (p)	SS	26.1	28.4	27.7	21.4
	PC	25.7	26.5	24.2	18.1

Animal health & fertility

No major health problems were recorded in either system. In both systems and compared with many conventional and organic herds (Kossabaiti & Esslemont, 1995; Siarra & Baumeler, 1997) the average number of cases of clinical mastitis both during lactation and the dry periods was relatively low throughout the project (SS – 14.4; PC – 18.2). Only a few cases of environmental mastitis (e-coli, *Streptococcus* spp.) were recorded with *Staphylococcus* spp infections identified as the main problem causing high cell counts (see below). Compared with the SS system the incidence of lameness was markedly higher in the PC system (SS – 13.7; PC – 20.0) and may be a reflection of the higher proportion of concentrate feeds in the diet. The incidence of clinical metabolic disorders was low in both systems, however, as stated in Section 4.3.2 the high milk fat to protein values with some animals (particularly in the SS system) during early lactation indicates the presence in some cows of sub-clinical ketosis. The grazing swards were managed to avoid daily fluctuations in the quantity of herbage that was available to each herd and no bloat problems were recorded in either herd during the project despite the grazing of clover-rich swards. No cases of hypomagnesaemia were recorded during the project and as shown by a previous study this appears not to be a major health problem on organic dairy farms (Weller & Bowling, 2000) and may reflect the improved uptake of magnesium by plants on organic farms.

The average somatic cell count in the milk from cows in both systems was higher than the UK average of 185,000 for conventional herds (NMR, 2001) and slightly lower than the average of 322,000 cells/ml reported by Nielsen (2001) for 504 organic dairy herds in Denmark. In the Danish study only 25% of the herds recorded average cell counts of 250,000 or less. High cell counts are associated with sub-clinical mastitis and a reduction in the processing quality of the milk, including an increase in proteolysis and coagulation time and a reduction in curd firmness (Okigbo *et al*, 1985; Klei *et al*, 1998). In addition to the above concerns increased cell counts are also correlated with lower milk yields (Rajala *et al*, 1999). Monthly milk samples that were taken from a small number of cows in each of the Ty Gwyn herds showed cell counts to be consistently >500,000. Bacteriology on these samples by the Veterinary Laboratories Agency showed *Staphylococcus aureus* to be the main pathogen, however, in some samples the reason for the high cell counts was not established with no specific pathogens identified. The cows with the high cell counts had a major influence on the average cell count in each herd leading to a skewed distribution and large differences between the mean and median values (e.g. In November 2001: SS – mean 238,000, median 107,000; PC – mean 300,000, median 136,000. The occurrence of *Staphylococcus aureus* infections in conventional herds has been identified as the prevalent mastitis pathogen (Roberson *et al*, 1998), with the problem either reduced or eliminated by the use of long-acting antibiotics in the dry period or the culling of infected cows. The strategy in both the two Ty Gwyn herds and other organic herds is limited to either increasing the culling rate or using alternative remedies. Increased dairy hygiene and also the use of different remedies for treating *Staphylococcus* infections and reducing cell counts have been tried at Ty Gwyn, with varying short-term success but without a longer-term solution to the problem. Other studies have also shown varying rates of success in reducing infections when either alternative treatments to antibiotics are used (Klocke *et al*,2000) or dairy hygiene is maintained to very high standards (Hutton *et al* ,1990). Although extra sodium in the diet has been reported to reduce cell count levels (Phillips *et al*, 1996) the free availability of rock salt to the two Ty Gwyn herds does not appear to have had any significant affect on reducing cell counts.

An increase in post-calving problems (retained foetal membranes, metritis) and poorer reproductive performance could indicate a mineral deficiency in the diets (Jacklin, 1993; Webster, 1997) in the two herds and Offerhaus *et al* (1994) reported a higher incidence of problems in organic herds than in conventional herds. However, in the current project the overall differences between the two herds in post-calving problems were small although as shown in Table 11 conception rates were lower in the SS herd and attributed to the lower energy density of the diets that were fed. Large differences were recorded between years in the number of cows with metritis and in the SS system the number of cases declined significantly during the project

The average culling rates during the project were 19.5 (SS system) and 17.4% (PC system), slightly lower than the 25% that was predicted in the Development Plan. The culling rates were similar to the average culling rate of 15.8% in 13 other UK organic dairy herds (Hovi *et al*, 2002) and an average of 23% in Norwegian organic herds (Reksen *et al*, 1999). However, the culling rates in the SS and PC systems at Ty Gwyn are significantly lower than the average of 40% reported by Kristensen & Pedersen (1995) for Danish organic herds, including a culling rate of 56% in one herd. In these herds the average milk production is 7,158 kg/cow and to maintain this high level of production many cows are culled due to low milk yields.

Table 11. The annual reproductive performance of the two herds

	Target	1999	2000	2001
<u>SS system</u>				
Number of serves/pregnancy	2.0	2.08	1.94	1.70
Days to conception: mean	<100	113	135	128
median		101	120	122
Pregnancy rate of served cows (%)	85-90	98.0	82.6	83.3
First service conception rate (%)	50-55	40.0	46.2	68.0
<u>PC system</u>				
Number of serves/pregnancy	2.0	2.02	1.66	2.07
Days to conception: mean	<100	106	130	134
median		83	135	129
Pregnancy rate of served cows (%)	85-90	83.7	88.6	90.4
First service conception rate (%)	50-55	46.5	54.5	44.7

The average number of serves per conception in both herds was lower than the average reported for commercial organic dairy herds (Hovi *et al*, 2002). Following a reduction in the level of concentrates being fed the pregnancy rate in the SS system was lower than the target, raising the question of whether the introduction of another breed into the herd or cross breeding would improve reproductive performance. In a comparison of different breeds of spring-calving cows fed the same high-forage diet (Dillon *et al*, 2001), Montbelliarde cows achieved a better conception rate than Holstein cows (91.2 v 73.7%) and also had a calving interval that was 17 days shorter. However, better reproductive performance was balanced by a lower milk yield (875 kg/cow) in the Montebelliarde cows.

ORGANIC DAIRY FARMING MODELLING

The aim of the modelling work was to enable a large number of strategies to be considered in relation to their physical and financial performance and the potential effect of the different strategies for commercial organic dairy farms and the two Ty Gwyn systems. The work utilised production and financial data from the two dairy herds at Ty Gwyn to validate computer simulation models that, in turn, were used to model a much broader range of organic dairy farm systems. Data from three case study commercial organic dairy farms and also from other organic dairy farms were used as the basis for the modelling process. The case study farms were selected to represent a range of farming systems in terms of farm size, concentrate use and location.

Methodology

Three different milk production scenarios were selected to model Table 12. They represented extreme variants of strategies that are found on organic farms in the UK, ranging from predominantly self sufficient (high efficiency of resource use) through to relying heavily on imported feeds (generally more intensive, profitable systems). The three main systems are:

1. Arable - home-grown forage and concentrates
2. Forage – forage fed without concentrates
3. Purchased – home-grown forage and purchased concentrates

The Arable and Purchased systems are demonstrated on the Ty Gwyn farm.

Table 12: Case study farm definitions

Farm location	Farm objectives	Type	Strategy	Representing scenario
Shropshire	To feed the herd with home-grown forages and minimal concentrates	Lowland dairy, long-term fully organic	All forage, no concentrates system	Forage
Pembrokeshire	To be self sufficient in terms of feeding the herd	LFA mixed dairy, long-term fully organic	Forage/arable system with no purchased concentrates	Arable
Devon	To produce as much milk as possible within the constraints of the organic production standards	Lowland dairy in conversion	All-forage system with purchased concentrates	Purchased

Models used:

1. SAC Dairy Systems model

This model is based on a grass-white clover swards system and simulates the milk production of a rotationally grazed dairy herd. Data required to run the model includes: climatic data (daily rainfall, temperature, potential evaporation rates), soil water capacity, soil-N availability, manure application rates, grazing strategy (stocking densities, length of grazing season), calving pattern and concentrate supplementation.

2. SAC FeedByte model

This model contains a database of feeds that can be edited to include organic feeds. The model consists of a lactation planner, a mixture evaluation module, a mixture formulation module and a relative feed value module. Data required to run the model includes annual lactation yields and liveweight change.

3. IRS OrgPlan

The model uses input and output data from existing enterprises to evaluate a pre-determined set of outcomes.

Steps in the modelling:

1. Run the Dairy Systems model
2. Use the output from Step 1 as an input into the FeedByte model
3. From Steps 1 and 2 the summer and winter feed requirements were identified
4. Rejection of any potential farm systems requiring >40% concentrates in the total diet
5. Input the combined sets of data into the OrgPlan model
6. Use OrgPlan to produce a number of outputs of sustainable and financial indicators

Results

The sensitivity analysis indicated that changes in the milk price affected the gross margin per hectare of some farms more adversely than others. The majority of the purchased feed systems appeared to be more sensitive to changes in the milk price than the arable or forage systems, as the % decrease in GM/ha with a decrease in milk price is greater in purchased feed systems. The purchased feed systems are more sensitive to changes in milk price because of the concentrates that need to be bought. Any decrease in concentrate price is going to decrease the GM/ha of these systems.

Sustainability indicators (Table 13) were calculated from the available data for each of the model systems, to attempt to identify the best balanced systems in terms of profitability and resource-use sustainability. The twenty-one viable systems modelled by OrgPlan were used for this process and indicators were calculated for the systems using both the production based and flat rate concentrate feeding strategies.

The two Ty Gwyn systems were also summarised using the sustainability indicators (Table 13). The financial indicators were whole farm gross margin per hectare, per cow and per litre of milk, and kg of purchased concentrate/£ gross margin (GM). The resource indicators were P and K farm gate balances, kg of purchased concentrates/litre of milk produced and the N-surplus (g)/litre of milk produced. Each indicator was calculated for the 21 model systems for two concentrate feeding strategies (FR = flat rate; PB = production based) and the two Ty Gwyn systems. It should be noted that the data from the two Ty Gwyn systems was taken from the early part of the project before the SS systems was fully established and based only on home-grown forage + concentrate feed. Therefore, using data from a period later in the project would have had a marked effect on the results with significant differences shown between the performance of the two systems.

Identifying the best system is dependent on the objectives of the individual farmer, the farmer's skills and the available set of physical resources. The results of the modelling suggest that as a general rule the arable scenario systems, which rely on home grown concentrate feeds, are more financially and resource-use efficient than purchased feed scenario systems which rely on importing concentrates. Systems based on high yielding, autumn calving cows and purchased concentrates tend to outperform those based on more self-sufficient systems with moderately yielding cows calving either in the spring or in two separate periods during the year.

A limitation of the modelling process was the complex processes of the individual models which calculated outputs in different formats, relied on different variables for calculations and modelled different parts of the production season which made the interpretation of a whole year's results difficult.

Table 13: Ranking of the main model systems based on financial and resource use indicators (1 = best performance)

1. Financial indicators					
Climate	Scenario	PB rank	Climate	Scenario	FR rank
S	P	11	S	P	9
P	P	10	P	P	9
S	P	9	S	P	9
P	P	9	P	P	9
Ty Gwyn PF	P	8	Ty Gwyn PF	P	8
Ty Gwyn SS	A	7	Ty Gwyn SS	A	7
S	F	6	S	F	6
S	F	6	S	F	6
P	F	6	P	F	6
P	F	6	P	F	6
P	A	6	S	A	6
D	F	6	D	F	6
S	A	5	S	A	5
S	A	5	P	A	5
P	A	5	D	F	5
D	F	5	P	A	5
P	P	4	P	P	4
S	P	4	S	P	4
S	F	3	S	F	3
D	F	2	D	F	2
P	F	2	P	F	2
S	A	1	S	A	1
P	A	1	P	A	1
2. Resource-use indicators					
Climate	Scenario	PB rank	Climate	Scenario	FR rank
S	F	7	P	P	6
P	P	7	P	P	6
S	F	7	S	F	6
P	P	6	S	F	6
S	P	6	S	P	5
S	F	6	S	P	5
S	A	6	S	F	5
S	P	5	P	P	5
P	P	5	Ty Gwyn SS	A	4
Ty Gwyn SS	A	5	P	F	3
S	P	5	P	F	3
P	F	4	D	F	3
P	F	4	P	F	3
S	A	4	S	A	3
D	F	4	Ty Gwyn PF	P	2
P	F	4	S	A	2
S	A	4	S	A	2
Ty Gwyn PF	P	3	P	A	2
P	A	3	S	P	2
P	A	3	D	F	1
D	F	2	D	F	1
D	F	2	P	A	1
P	A	1	P	A	1

Codes: S, P and D = Shropshire, Pembrokeshire and Devon.
P, A and F = Purchased, Arable and Forage
PB = concentrates fed according to production, FR = flat rate concentrate feeding.

ORGANIC DAIRY FARM INCOMES 1998/99 – 2001/02

The aim was to monitor the changes in the performance of both organic and in-conversion dairy farms during the 1998/99 to 2001/02 period. Compared with previous years this period saw major changes in the price paid for organic milk. In 1998/99 some organic farmers received 30 p/litre for their milk compared with conventional farmers receiving 18 p/litre, however, by the spring of 2001 the price paid for organic milk fell sharply leading to significant changes in farm incomes. The financial performance of Ty Gwyn and ten commercial organic dairy farms was monitored. Of the ten commercial farms four had been organic for a number of years, three were recently converted and three were in conversion.

Methodology

Data was collected using the methodology and protocols of the Farm Business Survey with the additional recording of physical details from the dairy enterprises. On all the farms the financial year was from the beginning of April to the end of March in the following year. As the farm and herd was not divided into two systems until October 1998 the financial data for Ty Gwyn in the 1998/99 period was derived by dividing the whole farm figures into half for the period up to October. Although all the milk from both systems at Ty Gwyn was stored in the same bulk tank, the milk quality (fat, protein & hygiene) from the individual cow's in each system was regularly tested allowing separate milk prices to be calculated for each system. A major difference between the Ty Gwyn herds and the commercial farms was the higher labour costs and also the charging of field operations (silage making, re-seeding etc) at contractors rates as derived from Nix (1999, 2000, 2001) and the Organic Farm Management Handbook (1999, 2002).

Results

The following table (Table 14) shows the farm type and performance in the first year of the study.

Table 14. Summary data for the study farms in 1998/99

Farm	Farm type	Herd size	Replacement rate %	Milk yield /cow (litres)	LSU per forage area	Concentrates fed (t/cow)	Milk from forage (litres)	Milk price (p/litre)
TG	LFA	90	21	5,179	2.0	1.08	3,000	28.7
1	LFA	51	16	5,744	1.5	0.62	4,480	28.1
2	Lowland	113	27	6,086	0.8	1.68	2,665	31.9
3	Lowland	67	27	5,888	1.8	0.67	4,524	31.2
4	Lowland	295	35	6,070	1.2	2.07	1,543	31.9
5	Lowland	89	45	5,195	1.5	1.03	3,098	26.9
6	Lowland	49	49	5,169	1.4	1.49	2,134	31.5
7	LFA	75	27	5,617	1.4	1.45	2,664	25.4
8	LFA	186	35	5,854	1.5	1.55	2,698	20.1
9	Lowland	89	29	8,238	1.9	2.70	2,740	18.7
10	Lowland	82	34	6,300	2.1	1.40	3,449	19.8

Code: TG = Ty Gwyn farm prior to the division into two systems. Farms 1-4 = long-established organic farms Farms 5-7 = recently converted farms   Farms 8-10 = in-conversion farms

The net farm income of the Ty Gwyn SS system increased from 1998/99 to 1999/00 to a peak of £25,453 but then declined sharply following a fall in the price paid for organic milk to a loss of -£14,269 in 2001/02. In the Ty Gwyn PC system the net farm income increased to £24,122 in 2000/01 but then fell sharply to a loss of -£4,825 in 2001/02.

The average peak net farm income on the commercial farms (Table 15) was recorded in the 1999/00 period, with either a small loss (-£5/ha) recorded on the well established farms or a small profit (£26/ha) in 2001/02 (see the following table). The price paid for organic milk decreased by 6 ppl from 2000/01 to 2001/02.

As well as the decreased milk price other management factors also influenced the decrease in farm outputs including changes in herd numbers, changes in the cropping strategy and the repayment of overpaid environmental grants. Labour costs on the recently converted farms increased by over £110/ha over the period of the study due in part to the vegetable enterprises on two of the farms. Stocking densities remained relatively constant on the organic farms.

Table 15. Average output, input and net farm income of established organic farms (£/ha)

1. Established organic farms	1998/99	1999/00	2000/01	2001/02
Dairy	688	770	743	649
Other cattle	89	82	76	73
Other livestock	44	58	47	46
Forage & arable	343	425	377	324
Miscellaneous	52	82	89	36
Total inputs	1,216	1,417	1,331	1,128
Livestock costs	287	318	306	262
Crop costs	90	89	55	68
Labour	279	294	247	219
Machinery	217	246	243	264
General	86	78	85	82
Land & rental	167	165	212	237
Total inputs	1,125	1,190	1,147	1,133
Net farm income	91	227	184	-5
2. Recently converted farms	1998/99	1999/00	2000/01	2001/02
Dairy	971	981	797	600
Other cattle	114	95	120	125
Other livestock	0	0	0	0
Forage & arable	294	570	647	306
Miscellaneous	43	102	88	95
Total inputs	1,422	1,749	1,653	1,125
Livestock costs	372	296	258	194
Crop costs	132	235	229	87
Labour	143	175	206	255
Machinery	241	375	338	310
General	82	73	63	69
Land & rental	167	167	187	185
Total inputs	1,137	1,321	1,281	1,099
Net farm income	284	427	372	26