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SID 5 Research Project Final Report

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Project identification

1. Defra Project code: OF0317

2. Project title: The development of organic milk production systems

3. Contractor organisation(s):
   IGER
   Trawsgoed Research Farm
   Trawsgoed
   Aberystwyth
   Ceredigion
   SY23 4LL

4. Total Defra project costs: £ 520,737

5. Project: start date .... 01 October 2002

   end date .... 30 September 2006

6. It is Defra's intention to publish this form.
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Executive Summary

7. The executive summary must not exceed 2 sides in total of A4 and should be understandable to the intelligent non-scientist. It should cover the main objectives, methods and findings of the research, together with any other significant events and options for new work.

The main objective of the 4-year project was to provide both qualitative and quantitative information on the development of two contrasting organic dairy systems, including the benefits and limitations of each system and also the opportunities for improving the systems. The first system (SS system) was based on an extensive and sustainable system, with the objective of achieving a high level of self sufficiency and sustainability by minimising the importation of nutrients into the system. Therefore, the cropping rotation for the system included forage crops for grazing and conservation and also cereal crops to provide both grain (for feeding as a concentrate) and straw for bedding. The main objective of the second system (PC system) was to change from a cropping strategy that was based on a rotation to the establishment of multi-species leys and also maximise milk output per cow and per hectare by importing concentrate feeds into the system to maintain a more productive enterprise with an increased milk output from feeding larger quantities of concentrate feeds.

The two systems were based at the IGER Ty Gwyn farm in West Wales, with the Holstein-Friesian dairy herd in each system managed on a land area of 30.45 (SS) or 28.0 ha (PC). Each herd was housed for six months of the year from mid-October to mid-April when diets were based primarily on grass+ clover silages, with the herds grazing the herbage from swards of both grass + clover re-seeded leys and permanent pastures during the other six months. Soil samples were taken from all the fields in each system at 2-yearly intervals. Monthly samples were taken from the grazing fields to measure both the yield and botanical composition of the herbage in the different swards, with the changes in the mineral and nitrogen concentrations also measured in four of the fields. Crops grown for conservation or combining were sampled prior to the cutting date. In addition the potential of new crops and plant mixtures was evaluated, including their yield potential and the relative cost of production. The physical performance and health of the individual cows within the herd was measured to provide a comparison between the systems in milk yields, milk quality, the efficiency of forage utilisation, efficiency of the conversion of nutrients into milk, incidence of specific health problems and reproductive efficiency. The farm-gate' nutrient budgets were also calculated annually for each system.

During the first two years of the project the performance of the cows in both systems was severely affected by the occurrence of liver fluke (*Fasciola hepatica*) which also led to a reduction in the reproductive efficiency of the two herds. In the 2004/05 period both herds returned to higher performance levels and acceptable pregnancy rates.

No significant differences were recorded between the systems in either soil or herbage mineral concentrations, despite the contrasting 'farm-gate' nutrient budgets which showed both a lower annual N-surplus and increasing deficit in the P & K balance in the SS system. This compared with an overall high annual N-surplus and small, but increasing, P & K balance in the PC system due to the importation of concentrates and straw for bedding. In both systems the concentrations of the majority of minerals (and also nitrogen) increased during the growing season and the mineral concentrations were within the ranges that have been published for conventionally-grown herbage. Despite large variations between fields in both the grass to legume ratios and soil P & K concentrations, no relationship was found between these parameters and annual yields.

Growing both forage and concentrate feeds in the SS system led to a stocking density that ranged from 1.08 to 1.28 cows/ha, with c.17% of the total land area used annually for grain production. The annual total grain production from the barley and triticale crops determined the quantity of concentrates that was available for feeding to the herd with 0.329-0.666 t fed per cow, leading to the milk yields ranging from a rolling average of 4,301-4,755 litres/cow, annual milk yields from 5,192-6,492 litres/cow and 4,817 to 6,695 litres being produced per hectare. Between 73.4 and 86.0% of the annual milk output was produced from forage (i.e. grazed herbage, silage).

As fields became due for re-seeding in the PC system, a multi-species ley was sown to replace the existing crop rotation. The key objectives of these leys were to sow species that were adaptable to the different soil types within the system, reduce forage costs, avoid the long periods in a rotation between the harvesting of the previous crop and initial production of the succeeding crop, and also provide a 10-year ley suitable for both cutting and grazing. The results from the multi-species leys, currently in their early-development stage, showed: (a) increased species diversity when compared with the standard organic leys that are widely established, (b) a non-uniform establishment of the species due to variations in the soil profile and water-retention capacity and (c) yields comparable to those recorded from leys with limited species diversity. Multi-species leys have the potential to improve the compatibility between soil type and plant species and also the need to respond to the changing climatic conditions in the UK.

Purchasing concentrate feeds in the PC system, rather than growing grain crops within the system, and also the option of purchasing additional feed when annual forage yields were inadequate, allowed a higher stocking density to be maintained (1.54 to 1.96 cows/ha) compared with the stocking density recorded in the SS system. The output of milk was also higher with the rolling average yield ranging from 5,204 to 6,810 litres/cow, annual milk yields from 5,893 to 8,086 litres/cow and between 8,743 to 12,532 litres being produced per hectare. The level of concentrate feeding was determined by the actual daily milk yield of the individual cow and led to an average of between 1.341 and 1.743 t/cow being fed, leading to 35.4 to 53.2% of the total annual milk being produced from forage. The efficiency of feed energy utilisation for milk production was higher in the PC system (33.7-39.8%) compared with the SS system (26.6-29.8%), attributable to the greater proportion of feed used for milk production rather than body maintenance. The yield of milk fat + protein ranged from 392 to 487 kg, markedly higher when compared with the yields of 331 to 420 kg in the SS system.

The Holstein-Friesian dairy cows were well suited to the PC system where the concentrate input was >1.0 t/cow/annum. However, in the SS system where the quantity of concentrates fed was dependent on the annual grain yields from the cereal crops there was insufficient feed energy in the total diet during the early lactation period leading to problems of reduced milk persistency during lactation, lower milk protein concentrations and either delayed conception or a failure to conceive that resulted in reduced pregnancy rates. The results show that in a system where the quantity of concentrates fed is low a different type of cow (e.g. dual-purpose breed, cross bred) would have the potential to improve the balance between the cow's nutrient requirements and the quality of the diet and also lead to an improvement in the quality of milk that is produced for both the liquid and processing markets.

The incidence of liver fluke adversely affected the cows in both systems during the early part of the project and led to the routine use of a preventative treatment. The cases of clinical mastitis and lameness were higher than in the previous study (during which period the systems were established), but the total number of cows in each herd was relatively small for carrying out this type of analyses on specific ailments. The reproductive performance was low immediately following the liver fluke problems, but re-covered to a satisfactory level at the end of the study.

Compared with the PC system, the SS system achieved a high level of self sufficiency but required a more complex crop rotation and was less flexible in relation to meeting the total annual feed requirements for the herd and also more limited when diets were formulated to balance the energy to protein ratio and meet the cow's nutrient requirements. While the stocking density of the PC system was markedly higher than in the SS system, if the area of land that would be required for producing the concentrate feeds is calculated, then the stocking density and output of milk per hectare in the system would be sharply reduced.

To date there have been no adverse physical effects recorded in the SS system in relation to both the growth and yield of the crops or animal health, despite the exporting of nutrients from the system. However, the time period since the establishment of the system is relatively short (i.e. seven years); therefore the effect of the increasing magnitude of the decline in nutrients may not have yet reached a critical point when problems will be apparent in crop and/or animal performance and health.

Analysis of the combined data collected from both the two Ty Gwyn systems and the six stakeholder farms shows a wide range in both the size of the individual enterprises and the approach to the management of the farm, with the source of the concentrate feeds (i.e. home-grown or purchased) one of the key factors. The cropping strategies were also diverse including the proportion of permanent pastures, short-term leys and medium-term leys on the individual farms. There was a wide range in the performance of the different systems, including the efficiency of nitrogen utilisation for milk production. Despite the diversity within the eight systems, analysis of the data that was collected suggest all to be viable in relation to the physical management of the farms and also financially viable providing a satisfactory price was received for the for the milk being sold from the system.

The results from the study show that aiming for a high level of self sufficiency in an organic dairy system (SS system) can be achieved by producing all the feed for the dairy herd within the system and via a crop rotation that includes both combinable and forage crops. The ratio of N-demanding to N-fixing crop is s a critical factor in ensuring there is adequate nitrogen for optimal crop production. The system was markedly influenced by the seasonal effects on total crop production and the proportion of land allocated for combinable crops. A failure to grow and feed sufficient grain within this type of system leads to low energy diets, reduced milk persistency, lower milk protein concentration and reduced herd fertility when Holstein-Friesian cows are managed within the system. The PC systems are less sustainable, more vulnerable to market trends in both the supply and price of purchased feeds but easier to manage, they do not necessarily require the implementation of a crop rotation, have the potential to both produce a higher output of milk per unit area of land and also improve the supply of feed energy to the cow in the critical early lactation period.

8. As a guide this report should be no longer than 20 sides of A4. This report is to provide Defra with details of the outputs of the research project for internal purposes; to meet the terms of the contract; and to allow Defra to publish details of the outputs to meet Environmental Information Regulation or Freedom of Information obligations. This short report to Defra does not preclude contractors from also seeking to publish a full, formal scientific report/paper in an appropriate scientific or other journal/publication. Indeed, Defra actively encourages such publications as part of the contract terms. The report to Defra should include:

- the scientific objectives as set out in the contract;
- the extent to which the objectives set out in the contract have been met;
- details of methods used and the results obtained, including statistical analysis (if appropriate);
- a discussion of the results and their reliability;
- the main implications of the findings;
- possible future work; and
- any action resulting from the research (e.g. IP, Knowledge Transfer).

Abbreviations used in the report: SS = Self-sufficient system PC = Purchased concentrate system

Section 1: Introduction

The main objective of the study was to develop the efficiency and performance of the two contrasting systems of organic milk production at the IGER Ty Gwyn organic dairy farm. Currently many organic dairy farms in the UK (whether based on a high level of self sufficiency or reliant on purchased concentrate feeds) produce and feed low energy diets that leads to a low efficiency of feed utilisation and poor production of milk from forage. The fluctuating price that is often paid for organic milk and the relatively expensive cost of purchased organic feeds have increased the importance of improving the efficiency of crop production and efficiency of feed utilisation to ensure organic dairy farming remain a viable option in the UK for both existing dairy farmers and those contemplating converting from conventional to organic dairy farming.

A key aim of the study was to provide farmers, advisers and policy makers with relevant information on improving the performance of contrasting organic systems including the implications of increasing the level of self sufficiency and the benefits and limitations of the system compared to a system based on purchased concentrate feeds. The study also provides information on the longer-term effects of self-sufficiency on the nutrient supply within the system for crop production and influence of the management strategies on the performance, health and fertility of the dairy cows managed within the system.

The objectives and milestones that were listed for the project have been met throughout the project and all the milestones met on time.

Section 2: Methods

Summary

1, Sites: Two separate dairy systems on the IGER Ty Gwyn organic dairy farm, West Wales. Total land area - 78.72 ha. Breed of dairy cows: Holstein-Friesian.

2. Soil sampling: Bi-annual sampling of soils from all fields in each system.

3. Nutrient budgets: Annual 'Farm-gate' nutrient budgets for each system including all inputs (feed, nitrogen fixation by legumes, mineral supplements, purchased straw, rainfall, purchased feeds) and outputs (milk, culled animals, surplus feed).

4. Crop measurements: Different cropping strategies in the two systems with yields from the grazing fields recorded monthly throughout the growing season and the yields from fields cut for silage/harvested for grain measured on the harvest date.

5. Crop quality: Chemical analyses of herbage and grain samples to determine the nutritive quality of the crops in each system.

6. Milk production and milk quality: Milk yield and milk composition recorded for each cow in the two systems on a monthly basis.

7. Herd health and reproductive events: Recorded daily for the individual cows in each system.

8. Herd performance parameters: Total crop energy output, efficiency of feed utilisation, stocking density, herd performance, herd health status & reproductive efficiency. All measured annually for each system.

9. Comparison of the physical and performance data from the two Ty Gwyn systems with data from six UK commercial stakeholder farms: data collated over a 3-year period prior to analyses.

2.1 Experimental resources used for the study

The study was carried out on the Ty Gwyn organic dairy farm located in West Wales at the IGER Trawsgoed research farm. Ty Gwyn was initially sub-divided into two separate dairy systems in the 1998/99 period. The total land area in each system was 30.45 (SS system) and 28.0 ha (PC system), with an additional 20.27 ha allocated to rearing the replacement animals for the two herds. The land area on the farm was classified as primarily Grade 3B with a small area of Grade 3C land. The land was primary sandy or silty-clay loam over gravel, with a smaller area of deep silty loam. The average annual rainfall on the farm was 1,253 mm. In each system the physical resources included three separate silage clamps, two slurry storage tanks, two calving boxes and a cubicle shed with the capacity for up to 60 cows during the 6-month winter housing period. Throughout the project the farm was inspected and registered by the Soil Association as a registered organic holding and the milk produced was sold to the Organic Milk Suppliers Cooperative. The farm was also inspected annually on behalf of the milk buyer (OMSCO) and reached the standards required by the National Dairy Farm Assurance Scheme (NDFAS). During the project the farm was also used as both a demonstration and teaching facility

2.2 Soil sampling procedures and the strategy for the utilisation of slurry within the two systems

Core soil samples to a depth of 20 cm and representative of the full depth of the plough layer were taken at 2-yearly intervals to determine the changes in the soil nutrient concentrations. Apart from applications of lime to fields with a pH below 5.5, no other organic fertilisers were applied in either system. The main nitrogen input into the systems was via N-fixation by legumes (primarily white clover), with additional nitrogen for the PC system imported into the system from the purchased concentrate feeds, particularly from the protein feeds i.e. field beans and linseed. In both systems the management strategy to ensure soil P and K indices were maintained was to prioritise which land areas should receive the main applications of slurry, with a maximum of three applications of slurry applied to fields with a high nutrient removal due to the cutting and removal of three silage crops during the growing season. Grazing fields received only one annual application of slurry. The higher stocking density in the PC system led to a higher production of slurry and allowed higher quantities of slurry to be applied to the fields within the system; however, the proportion of total nutrients being recycled within the system was lower due to the high level of imported concentrate feeds and also extra straw that was required for bedding.

2.3 Calculation of the nutrient budgets for the two systems

'Farm-gate' nutrient budgets were calculated annually for the two systems at the end of the winter housing period (e.g. April), with the figures calculated using quantitative measurements within the systems and published calculations for the individual components of the budgets that included N-fixation rates by legumes. The budgets were calculated for the dairy herds in the two systems and did not include the young animals being reared as replacements.

2.4 The cropping strategy for the two systems

Table 1: The field cropping plan for the two systems.

	Year 1	Year 2	Year 3	Year 4
SS system:				
Field 1	PP	PP	PP	PP
2	PRG + WC + H	PRG + WC + H	PRG + WC + H	PRG + WC + H
3	Winter barley	RC	RC	RC
4	Winter triticale	Winter barley	PRG + WC +H	PRG + WC + H
5	IRG + RC	IRG + RC	IRG + RC	Winter triticale
6	PRG + WC + H	PRG + WC + H	PRG + WC + H	PRG + WC + H
7	PRG + WC + H	PRG + WC + H	PRG + WC + H	PRG + WC + H
8	IRG + HRG + RC	IRG + HRG + RC	Winter barley	PRG + WC + H
9	RC	Winter triticale	PRG + WC + H	PRG + WC + H
10	PRG + WC + H	PRG + WC + H	PRG + WC + H	Winter triticale
PC system:				
Field 1	PP	PP	PP	PP
2	PRG + WC + H	WCC + Multi-species ley A.	Multi-species ley A. Multi-species ley A.	Multi-species ley A. Multi-species ley A.
3	PRG + WC + H	WCC + Multi-species ley A.	PRG + WC + H WCC + Multi-species ley B.	PRG + WC + H Multi-species ley B.
4	PRG + WC + H	PRG + WC + H		PRG + WC + H
5	PRG + WC + H	PRG + WC + H	PRG + WC + H PRG + WC + H	PRG + WC + H PRG + WC + H
6	PRG + WC + H	PRG + WC + H	PRG + WC + H	Multi-species ley C.
7	PRG + WC + H	PRG + WC + H	IRG + RC	
8	PRG + WC + H	PRG + WC + H		
9	IRG + RC	IRG + RC		
10	PRG + WC + H	PRG + WC + H	PRG + WC + H + Slot seeding grass Into the existing ley	PRG + WC + H

Key: PP = permanent pasture, PRG + WC + H = perennial ryegrass, white clover & herbs, RC = red clover, IRG + RC = Italian ryegrass + red clover, IRG + HRG + RC = Italian ryegrass + hybrid ryegrass +

red clover, WCC = whole-crop cereals

The cropping plan for the two systems is shown in Table 1. In the SS system a cropping rotation was established in nine of the fields with a permanent pasture maintained in the tenth field. The rotation included 5-year perennial ryegrass + white clover + herb leys for grazing and conservation, monoculture red clover to provide feed protein and autumn-sown barley and triticale cereal crops to provide grain for feeding as a concentrate feed and straw for bedding. In addition a number of different cropping options were evaluated on a small-scale to determine their potential for increasing the nutritive quality of the diets and their relative production costs. In the PC system, as fields became due for reseeding, different 10-year multi-species mixture were sown with the objective of reducing production costs and fossil energy inputs and to also provide more species-diverse leys suitable for both grazing and conservation. Different mixtures were established to provide good compatibility between the soil type of the individual field and also evaluate the potential of new species. Cereal crops grown for grain production or whole-crop cereals were sown at a seed rate of 200 kg/ha, with the rate reduced to 130-150 kg/ha when the crops were undersown with the succeeding ley mixture.

2.5 The procedures for the sampling of the crops in the two systems

Five exclosure cages per grazing field were used in both systems to allow samples to be cut at 2.5 cm above ground level at monthly intervals throughout the growing season (April-October) to determine the DM yields and proportion of clover in the herbage. In fields where either the herbage was either conserved as silage or cereal crops were combined for grain and straw, the yields were determined a day before the individual harvest. Samples were dried in a Unitherm oven at 70^0C, milled and sent to be analysed by Natural Resources Management Laboratories to determine the nutritive quality of the organic crops, including the changes in protein content and mineral concentrations. To compare the crop energy yields both between the systems and individual crops the Scandinavian Feed Units were calculated annually with the yields and energy values of the individual crops calculated as SFU using a conversion factor of 1 SFU = 12.9 ME. The results presented in the report for the results from the crop measurements include the data collected during the 2003, 2004 & 2005 growing seasons from March to October.

2.6 The procedures for determining the performance of the cows in the two systems

In both systems the Holstein-Friesian cows were the primary breed type. When the two systems were initially set up in 1998 the Defra Steering Committee members agreed that the Holstein-Friesian breed was the appropriate breed to manage within both systems, as the breed represented >92% of UK dairy cows. However, during the previous study (1998-2002) the results indicated that the organic diets were deficient in energy when rations were being formulated and , therefore, in the current study the cows were inseminated with semen from New Zealand-bred bulls with a high proportion of Friesian genetics to improve the suitability of the cows for high-forage system, particularly the SS system where the feed energy deficit was high during early lactation. Heifers calved for the first time at 2-years-old, with the aim of achieving minimum growth rates of 0.67 kg live weight gain per day from birth to calving. All young animals from birth to the date on which they entered the main herds as in-calf heifers, were reared together in a separate area from the two herds of cows. When insufficient replacement animals were available for the two herds a small number of organic heifers were purchased and allocated to the two systems.

The performance of the individual cows in the herd was determined monthly by National Milk Records and Promar International. The samples and data collected from the individual cows by National Milk Records included milk yields and analyses of milk samples to determine the fat, protein and somatic cell count concentrations. Data analyses by Promar International included both monthly and annual rolling averages for the performance of the two systems in relation to changes in milk yield, milk quality, forage utilisation, efficiency of concentrate utilisation and financial margins over purchased feeds. All health and fertility events were initially recorded in a daily diary and then collated on the computer software Interherd Dairy Information system. When specific health problems occurred in the two dairy herds a veterinary surgeon from the Ystwyth Veterinary Group visited Ty Gwyn with the practice also preparing and regularly updating a health plan for the two herds. In addition alternative remedies were obtained for milder cases of specific ailments and administered by the herdsmen. The milking parlour and associated equipment were inspected annually and routine maintenance carried out by Shropshire Dairy Supplies. The data presented for the dairy herds includes data collected in Years 1 (Oct 02-Sept03), 2 (Oct03-Sept04), 3 (Oct04-Sept05) & 4 (Oct05-June06).

2.7 The collection of data from six commercial stakeholder farms

During the 2003-2005 periods the physical performance of the two Ty Gwyn systems was compared with six stakeholder commercial organic dairy farms in England and Wales. The farms included in the study ranged from a farm recently converted to organic management to one that had been converted to organic dairy production more than 30 years ago. The farms had a diversity of climatic conditions, cropping strategies, level of self sufficiency and approaches to the management of the dairy herds. During each year the farms were visited and data collected to provide comprehensive information on each system that could be compared with the Ty Gwyn systems. The data collected from all the systems (including the SS and PC systems at Ty Gwyn) included both the dairy herd and the growing animals being reared as replacements.

During the project presentations on the progress of the work were made by the Project Leader at regular meetings of the Defra Steering Committee. The meetings provided the opportunity for members to review the progress of the project and provide expert guidance when required. The Committee members included personnel from Defra, Soil Association, SAC, IRS, ADAS and Stakeholder dairy farmers

Section 3: Results

3.1 Changes in the soil indices of the fields in the two systems

The analysis of the soil samples during the study is shown in Table 2, with the concentrations recorded when the systems were initially established in 1998 also included. The application of lime to fields when they were ploughed prior to establishing anew crop ensured the soil pH was maintained at a minimum of 5.5 in all fields The target of 5.5 was based on previous experience in the UK & New Zealand showing 5.5 was high enough for optimal clover growth and production. As shown in Table 2, despite the higher stocking density in the PC system, no marked differences were recorded between the two systems in either the average soil P or K concentrations. In both systems the range of soil P and K concentrations in the individual fields was large. Soil samples taken in 2006 show a trend of declining P and K soil concentrations in both systems since 1998. Magnesium concentrations increased in the PC system where extra nutrients were imported via the purchased concentrate feeds but decreased in the SS system.

Table 2: Nutrient concentration in the soils from the two systems

	Year	SS			PC		
Soil analyses parameter		Mean	s.e.	Range	Mean	s.e.	Range
Phosphorus (mg/kg)	1998	26.6	6.83	19-38	29.1	20.04	15-86
	2004	27.4	7.50	16-37	22.5	10.56	13-50
	2006	22.3	6.02	15-30	17.9	8.48	11-40
Potassium (mg/kg)	1998	138.1	40.36	79-193	156.4	64.73	90-276
	2004	116.2	32.63	74-178	134.2	41.59	81-225
	2006	128.7	51.77	49-217	131.7	61.63	69-228
Magnesium (mg/kg)	1998	156.1	48.56	106-270	146.7	36.38	108-214
	2004	100.2	41.40	40-168	119.7	40.06	76-196
	2006	109.5	33.90	53-169	122.5	38.87	66-201
pH	1998	6.0	0.27	5.7-6.4	6.2	0.34	5.5-6.5
	2004	6.1	0.35	5.6-6.6	6.2	0.34	5.7-6.6
	2006	6.0	0.23	5.7-6.3	6.1	0.34	5.6-6.6
Organic matter (%)	1998	7.1	0.66	5.9-8.0	6.6	0.53	5.9-7.6
	2004	6.7	0.59	5.6-7.6	6.4	0.73	5.1-7.4
	2006	7.0	0.67	6.0-7.8	7.0	1.28	5.9-10.2

The lack of information on the sulphur concentrations of organically-managed soils led to extra soil analyses being carried out at Ty Gwyn in 2003. Soil samples from two fields in each system were sampled in 2003 to determine their sulphur concentrations. The sulphur concentrations in the soil were similar in both systems - SS fields 21.5 & 24.7, PC fields 23.7 & 26.3 and within the ranges published for conventionally-managed soils.

3.2 Crop production in the two systems

3.2.1 Main cropping strategy and aims in the two systems

Crop production in both systems was based on achieving the correct balance between producing sufficient herbage for grazing during the growing season and also ensuring adequate feed was conserved for the winter period when the cattle were housed due to either a lack of fresh herbage for grazing or adverse ground conditions following periods of heavy rainfall. On average the grazing and housed periods were of 6-months duration and total forage requirements similar for both periods, with an allowance of 20% for ensiling losses in the conserved forages balanced by the lower intake of a higher proportion of late and non-lactating cows during the period of housing. In addition extra silage was held as a reserve for 'buffer' feeding during the late summer period should a lack of rainfall lead to insufficient herbage being available for the two herds. Silage rather than concentrates was the preferred buffer feed as (a) the higher fibre content of the silage balanced the high-clover and low fibre content of the herbage during this period, and (b) silage was a cheaper feed than concentrates, irrespective of whether the concentrate feeds were purchased (PC system) or home grown (SS system).

The objective in the SS system was to establish crops that would have the potential to ensure sufficient feed was available annually for the dairy herd in relation to both quantity and quality, as imported feed was only considered when adverse conditions (TB restrictions on exporting cull cows from the system, adverse weather conditions) led to extra feed being required or insufficient quantities being produced for grazing and conservation. During the primary growing season from March-October the fields in both systems with grass + legume species (i.e. reseeded short-term ley, re-seeded 5-year leys & permanent pastures) were managed as either grazing swards, conservation swards or swards that were conserved as silage in the spring and then grazed for the rest of the growing season. During the growing season the ratio of grazed to conserved areas of forage changed from 1:2 (spring) to 1:1 (mid summer), 2:1 (late summer), followed by 100% grazing of all the forage areas in the autumn period prior to housing. To ensure a balance was maintained between achieving good quality silage while ensuring sufficient quantities of silage were available for the winter period, three cuts were taken annually in May, June and September. Maintaining a minimum cutting height of 10 cm in the red clover-based swards ensured the crowns of the plants were undamaged, minimising the risk of a decline in the plant populations. All herbage seed mixtures and cereal crops sown in the systems were either directly available commercially or the mixtures formulated for the fields using individual species and varieties that were also commercially available. The need to increase the energy supply of the forage, especially in the SS system, led to high-sugar perennial ryegrass varieties being included in the mixtures. A key aim was to ensure dense swards were established to (a) prevent dock populations becoming established and causing a decline in the yield and quality of the leys and (b) to minimise the effects of poaching by the cattle and damage to the soil structure during periods of heavy rainfall. Therefore, depending on the different seed sizes of the species included in a mixture a minimum of 33 kg of seed per hectare was sown to ensure adequate plant populations were established and grass varieties with a good ground cover rating (NIAB classification) were included in the mixtures (e.g. perennial ryegrass variety AberGold).

3.2.2 The total yield from the fields in the two systems

Table 3 shows the total annual crop yields for each field for the growing season (March-October) in the first three years of the study. The contribution of legumes to the total yield have been classified as low (1-15), moderate (16-30) and high (>31%). A comparison of the yields from perennial ryegrass + white clover + herb leys of <5 years old that were grown in the two systems shows the average yield to be similar in the two systems (SS – 10.75, PC 11.23 t DM/ha). Excluding the high red clover swards and cereal crops, the contribution of legumes to the total yields was slightly higher in the PC system (20.3 v 16.9%) compared with the SS system. Despite large variations between fields in grass to legume ratios and soil P & K concentrations, when regression analyses was carried out on the data no relationship was found in either system between these parameters and the total DM yield.

Table 3: The crop DM yields (t/ha) and contribution of legumes to the total yield of grass/legume based leys and permanent pastures

	Year 1		Year 2		Year 3	
	Total yield	Legume contribution	Total yield	Legume contribution	Total yield	Legume contribution
SS system:						
Field 1	9.808	moderate	10.810	low	10.935	low
2	10.558	moderate	9.927	moderate	8.887	low
3	6.723	n/a	11.755	high	12.154	high
4	11.467	n/a	7.290	n/a	10.034	moderate
5	8.166	low	14.432	low	11.331	moderate
6	8.316	moderate	10.337	low	9.057	low
7	12.332	moderate	10.694	moderate	11.444	low
8	13.030	moderate	10.369	moderate	9.080	n/a
9	13.511	high	12.195	n/a	11.789	high
10	12.504	moderate	12.932	low	10.231	low
PC system:						
Field 1	9.448	moderate	10.356	low	10.132	low
2	9.717	moderate	11.530	high	11.712	moderate
3	8.359	low	12.980	high	10.959	high
4	11.695	moderate	10.697	low	10.402	low
5	9.712	moderate	11.192	moderate	12.481	high
6	12.825	moderate	12.025	low	13.312	low
7	12.172	high	13.068	high	13.039	moderate
8	11.248	moderate	11.390	low	10.434	moderate
9	12.863	moderate	14.153	moderate	7.198	moderate
10	12.431	moderate	12.870	moderate	13.311	low

3.2.2.1 The average crop energy production per hectare in the two systems

As has been shown in both previous studies at Ty Gwyn and also in other work, the production and availability of feed energy from crops is a critical factor in the perofrmance of organic livestock systems.

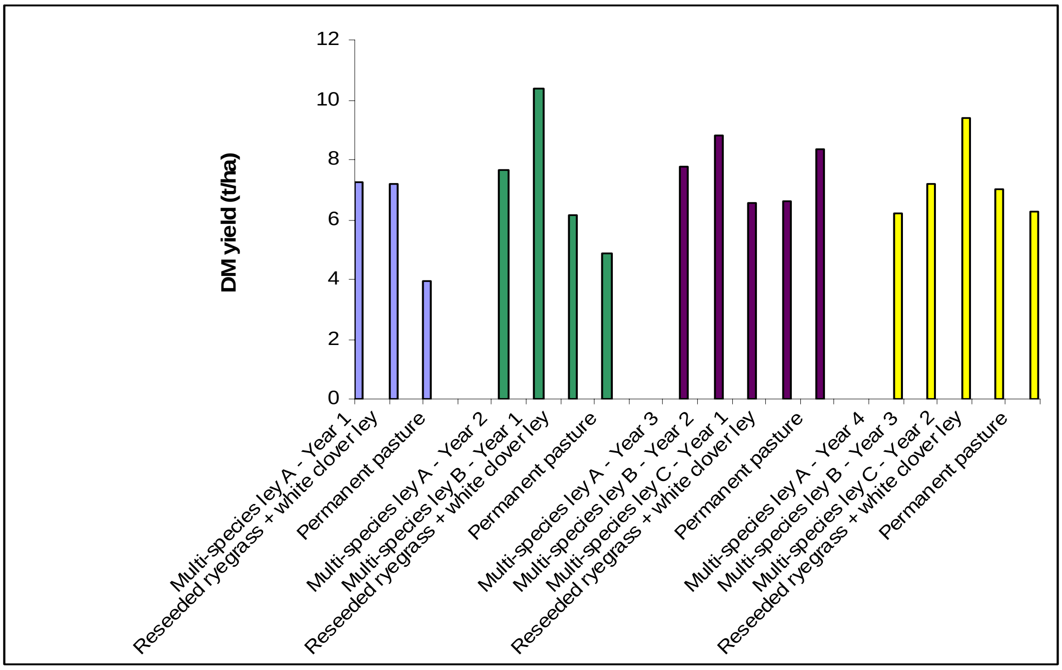
The crop energy production from the two systems at Ty Gwyn was calculated using Scandinavian Feed Units (SFU), with the energy values of each individual crop converted to SFU units using a conversion value of 1 SFU = 12.9 MJ. As shown in Table 4 the average SFU yield per hectare was consistently higher in the PC system where only forage crops were grown rather than in the SS system where nearly 20% of the land was allocated to the growing of barley and triticale for the production of cereal grains and straw. The total DM and SFU yields in the PC system were consistently higher than in the SS system with the highest DM yield recorded in 2004 but highest SFU yield recorded in 2003 when the average energy value of the crops was higher.

Table 4. The average crop energy yield per hectare calculated as Scandinavian Feed Units (SFU) and total annual DM yield (t) produced in the systems.

Year	SS system	PC system	Difference (t)
SFU (t/ha):			
2003	8.36	9.20	0.84
2004	8.45	9.06	0.61
2005	7.20	8.11	0.91
Total yield (t DM/ha):			
2003	10.07	11.46	1.39
2004	10.60	12.00	1.40
2005	9.22	11.40	2.18

3.2.2.2 Changing the cropping strategy in the PC system from a crop rotation to multi-species leys

Figure 1. The herbage yields from the multi-species leys in the four years after establishment compared with perennial ryegrass/white clover leys and permanent pastures.



A key aim in the PC system was to implement a progressive change in the cropping strategy from a rotation to the establishment of multi-species leys when fields became due for re-seeding rather than sowing monocultures (e.g. cereal crop, red clover) or a combination of only two species (e.g. perennial ryegrass + white clover, Italian ryegrass + red clover). There were four main objectives for establishment of the multi-species leys:

1. Sowing a range of plant species (grasses, legumes and herbs) that are adaptable to different soil types within an individual field, able to persist under different management strategies (e.g. grazing, frequent cutting, less frequent cutting) and climatic conditions both within and between growing seasons. Species sown in the different multi-species leys included hybrid ryegrass, perennial ryegrass (both intermediate and late varieties), timothy, cocksfoot, meadow fescue, creeping red fescue, smooth-stalked meadow grass, crested dogstail, red clover, white clover, alsike, birdsfoot trefoil, chicory, ribgrass, salad burnet and yarrow.
2. Reducing both the financial and fossil energy inputs by establishing leys that will be sustainable and self sufficient for a minimum of ten years.
3. Avoiding the unproductive period between the final harvests or grazing of the previous crop and the stage when the new ley reaches full production.

3. Increasing the flexibility of the whole cropping strategy within the PC system as multi-species leys would provide herbage suitable for both grazing during the spring to autumn period or conservation swards to provide silage for feeding during the winter period of housing.

The value of sowing multi-species leys was demonstrated from the visual examination of the leys which showed as predicted that a non-uniform establishment of the individual species had occurred in the total field area with, with for example timothy and meadow fescue grass species establishing in areas where the soils have a high water capacity and cocksfoot grass dominating the dry, shallow soils in other parts of the field. The establishment of the multi-species ley A has shown the benefits of including more than one legume in the seed mixture, with red clover providing the main N-fixation source in the first two years after sowing and white clover succeeding in Year 3 onwards as the main legume in the ley. Figure 1 shows the combined yields from the first two primary cuts from the multi-species leys in comparison to the yields recorded from two reseeded ryegrass + white clover leys and a permanent pasture. As shown by the yields in Figure 1, including a range of other species in the multi-species leys in addition to the standard perennial ryegrass + white clover seed ensured the productivity of the swards was not compromised by establishing a more diverse seed mixture. The mean yield from the combined multi-species leys was 7.993 t compared with 5.849 and 5.816 t DM from the permanent pasture and re-seeded leys, respectively. It should be noted that the multi-species leys are only in their second to fourth year after establishment and therefore the current results do not include the longer-term implications in relation to adaption to changes in climatic conditions, persistency, nutritive quality, weed control and other factors

3.2.2.3 Growing combinable cereal crops as the concentrate feeds in the SS system

A key factor in the SS system was the total yield of cereal grains produced annually as this determined both the quantity of concentrate feed that was available for feeding to the dairy herd and also the energy density of the total diet being consumed. As Ty Gwyn is located in a county that is primarily a grass pasture farming area (i.e. re-seeded grass leys, permanent pastures), damage to the cereal crops by a large population of rooks was a problem in previous years, not only in the 3-week period prior to combining but also, in the case of oat crops, severe problems during the sowing and seed emergence stages. Therefore, during the study barley and triticale were the cereals chosen for combining as these suffered minimal bird damage. Barley had previously proved a consistently reliable crop and triticale offered the opportunity of producing grain with a high energy value that is only slightly lower than that of wheat grain. In the SS system the costs of producing cereal grains as the concentrate feed varied during the study from £154 to £335 per tonne, due to differences in the yield of grain produced annually per hectare, with variations in seasonal climatic conditions and the different species being grown the major factors affecting yield. As shown in Table 5 the lowest grain yields were recorded in 2005 and attributed primarily to the difficulty of establishing winter barley during a wet autumn period in 2004, when ground conditions for cultivating the soil and sowing the crop. Both barley and triticale proved to be reliable crops for grain production despite Ty Gwyn being located in an area of high rainfall, however, the risk of the combination of a late harvest and wet autumn conditions favoured autumn rather than spring-sown triticale as the period from sowing to harvesting is significantly longer for the crop when compared with barley which is suitable for both autumn and spring establishment.

Table 5: Grain and straw yields from cereals crops grown in the SS system for combining to provide both grain for feeding to the dairy herd and straw for bedding.

Year	Cereal species	Variety	Grain yield (t DM/ha)	Straw yield (t DM/ha)
2003	Winter triticale	Taurus	3.67	1.32
	Winter barley	Pearl	3.25	2.13
2004	Winter triticale	Ego	4.72	4.65
	Winter barley	Pearl	3.83	2.18
2005	Winter barley	Pearl	2.87	1.44

3.2.2.4 The cost of growing different crops for feeding to the dairy herd in the SS system in relation to their nutritive value

Forage as the primary component of the organic diet has a major influence on both the financial viability of the organic dairy system and also the formulation of nutritionally-balanced diets. Therefore, evaluating the relative merits of different forage crops in terms of nutritive quality and costs of production is critical in assessing the viability of an organic dairy system. As shown in Table 6 there were major differences in costs between the forage crops and mixtures that were evaluated in the SS system, with the costs calculated not only for the costs of production but also on a nutritive value basis using the unit costs of energy and protein from the market prices for organic combinable grain crops (74 pence per 10 MJ of feed energy; 37.1 pence per kg of feed protein). Increasing the feed energy supply is critical in systems based on self sufficiency and the feeding of very high-forage diets that include fodder beet, and to a lesser extent forage maize, have the potential to increase the energy density of the organic diets. However, as shown in the table below although fodder beet is a high energy crop the costs of production were high when the crop was grown in the SS system at Ty Gwyn, including the costs associated with the requirement for 4-5 inter-row cultivations to ensure weed populations did not compete aggressively with the fodder beet plants and reduce the yields of the sown crop. In addition the protein content of the crop is low (5-6%), requiring additional feed protein to be added to the diet. In terms of costs feed protein is more expensive per tonne than feed energy, therefore, as shown in Table 6 the comparative nutritive value of fodder beet was lower than for the other crops.

Table 6. The evaluation of different crops and mixtures to improve the quality of the diets in the SS system.

Crop details	Energy value rating	Protein value rating	Yield (t DM /ha)	Cost of production (£/t DM)	Nutritive value (£/t DM)
Spring barley whole crop	M	L	10.30	50.2	102
Spring triticale + vetch	M	M	11.85	49.4	107
Fodder beet	H	L	8.50	99.1	101
Annual fertility-building ley	M	H	10.19	56.3	130*
3-year red clover/grass ley	M	H	10.36	43.0	130*
5-year white clover/grass/herb ley	M	H	9.68	44.1	130*
Permanent pasture	M	H	8.53	44.3	130*

* costs calculated when the crop are harvested at the same quality value and with comparable legume to grass ratios

3.2.2.5 The mineral concentration of the herbage grown in the two systems

As minerals in the diets fed to dairy cattle have a major influence on the health and welfare of the animals, including maintenance of the immune system and the prevention of specific disease problems in both the growing and lactating animal, the decision was made to evaluate the mineral concentrations in the forage produced in the two systems. During a 3-year period (2003-2005) the mineral and nitrogen concentration of the herbage from two fields in each system was measured twice during the growing season to determine if there were differences between the systems and also how the concentrations compared with herbage grown in conventional systems where the importation of nutrients into the system are normally significantly higher due to the routine feeding of mineral supplements and the overall higher importation of nutrients per hectare. The following table shows the average mineral and nitrogen concentration during the three years and also the conventional values published by Whitehead (2000). The results from the individual samples taken from each field show that the concentrations of phosphorus, magnesium, sulphur, copper, zinc, iodine and nitrogen increased markedly as the season progressed, selenium concentrations remained consistently very low. In some field's potassium, calcium, sodium and manganese concentrations increased during the season but in others either the levels decreased or remained stable. As shown in Table 7 the average concentrations in a number of the minerals, while within the range of conventional values, are in the lower quartiles of the range. No major differences were recorded between the mineral concentration of herbage in the SS and PC system during the 3-year period.

Table 7. The average mineral and nitrogen concentration of herbage from four of the grazing fields in the two systems.

Field:	1	2	3	4	Range in conventional values*
System:	SS	PC	SS	PC	
g/kg: Phosphorus	2,838	3,352	2,767	2,773	2,000-6,000
Potassium	23,923	24,049	25,105	27,709	15,000-35,000
Calcium	7,571	7,149	7,405	7,377	5,020-10,041
Magnesium	2,376	2,379	2,138	2,010	1,085-3,170
Sodium	2,419	4,188	3,074	2,668	500-4,000
Sulphur	1,854	2,453	2,320	2,372	2,000-5,000
Manganese	57	104	118	101	30-283
Copper	6.7	7.7	7.7	7.9	3.3-14.5
Zinc	35.3	46.8	42.9	44.2	16-57
Selenium	0.03	0.03	0.06	0.04	0.02-0.54
Iodine	0.61	0.58	0.51	0.72	0.10-0.50
% Nitrogen	2.69	2.67	2.91	2.80	2.26-3.8

* adapted from the data published by Whitehead (2000)

3.2.2.6 The protein content of the grazing swards during the growing season

In both systems the primary feed for the dairy cows during the April-October period was grazed herbage from either re-seeded leys or permanent pastures, with herbage contributing up to 100% of the total diet. Monitoring of all the individual fields during the study showed that during the grazing season the proportion of white clover in the herbage increases. As the protein content of white clover is higher than the content found in grasses this can have a major effect on the protein content of the diet, particularly in the SS system where only a small quantity of concentrates are fed during the lactation. To investigate the magnitude of the increase in the protein content of the grazed swards during the season, samples were taken from two re-seeded leys in each system by sampling the fields at monthly intervals. The results are presented in Table 8 below and show that the protein content increased in the herbage as the season progressed and the proportion of white clover also increased. These results show that unless cows grazing grass + white clover are offered a high energy/low protein feed (e.g. maize silage, cereals grains) the protein content of the diet is too high for the dairy cows and as reported in the published literature this will lead to a lower efficiency in the conversion of feed nitrogen into milk, with the levels from mid-summer onwards above the optimal level required to balance the diet of the dairy cow managed in clover-based systems. The fibre content of some of the swards in the two systems also fell below the level required by the dairy cow as the season progressed due to the high clover content in the total herbage.

Table 8: Changes in the protein content of herbage from re-seeded grass + white clover leys and days of the year.

System:	SS	PC	SS	PC
Ley management	Grazed	Grazed	Conservation followed by grazing	Conservation followed by grazing
Cut 1	16.3 126	13.2 133	12.2 152	12.0 152
2	15.3 157	16.1 167	14.6 202	19.4 190
3	27.8 182	16.4 197	20.7 231	19.8 231
4	14.5 205	19.6 231	20.4 259	21.9 259
5	21.6 247	21.9 259	25.4 289	21.6 294
6	22.4 289	22.9 289		

3.3 Evaluating new cropping options to increase the quantity and quality of the diets in the SS system

3.3.1 Evaluating quick-growing leys to provide extra forage

Short-term leys grown for ploughing-in as green manures to improve soil fertility are an important component of many organic systems, including those based on both agriculture and horticulture. These 3-6 month leys that include both rapidly growing legumes and grasses may also have an additional role on organic livestock farms, particularly in dairy systems where self sufficiency is a high priority or forage stocks below the normal level. To evaluate the potential of these leys three different mixtures were established on a small area at Ty Gwyn in 2003 and harvested 13, 19 and 26 weeks after sowing (4 April). As shown in Table 9 below high yields were recorded from the mixtures and the yields at first cut (13 weeks post-sowing) providing a significant quantity of herbage for either cutting and conserving as silage or ploughing-in, with the further options of either harvesting more herbage at subsequent cuts or ploughing in the green manure to increase the soil fertility for a new crop that is being established in the same growing season.

Table 9: The yields recorded from fertility-building leys with a rapid growth rate

	Mixture 1	Mixture 2	Mixture 3
% of each seed type:			
Westerwolds ryegrass	0	22.8	45.5
Italian ryegrass	40.9	25.5	11.4
Common vetch	45.5	33.6	21.3
Crimson clover	6.8	4.5	1.8
Red clover	6.8	13.6	20.0
Cut 1: 13 weeks after sowing			
DM yield (t/ha)	4.589	5.181	6.041
% legume	19	8	6
Cut 2: 19 weeks after sowing			
DM yield (t/ha)	3.574	3.373	3.606
% legume	20	11	15

Cut 3: 26 weeks after sowing DM yield (t/ha) % legume	 1.296 40	 1.048 45	 974 47
Total DM yield (t/ha)	9.459	9.602	10.621

Dried samples of the individual species from Cut 1 were sent for analysis and the results showed higher digestibility and protein values in the legume species compared with the grasses. The digestibility (% NCD) and crude protein (%) values were: Westerwolds ryegrass - 57.1 & 13.0, Italian ryegrass - 67.9 & 16.1, Common vetch - 70.3 & 21.0, Crimson clover - 69.8 & 14.3, Red clover 74.7 & 19.4. Vetch grown and sampled at different stages of growth from early flowering to full pod showed consistently high protein values (18-22%), irrespective of the stage of maturity of the plants. The fibre content of the legumes (30-36%) was lower than the grasses (45-58%). The dry weather led to the early maturity of the Westerwolds ryegrass at Cut 1 and the harvesting of a grass with a very low digestibility value.

One problem in both the SS and PC systems is the erratic supply of feed protein and potential environmental losses due to the energy to protein imbalance and poor utilisation by the animal in some periods of the year, while in other periods there is a shortage of feed protein. Sowing a mixture of complementary legume species in a mixture has the potential to provide a more balanced energy to protein supply in the herbage grown throughout the season by providing 'legume succession' within the ley as the season progresses. A combination of legumes has the potential to reduce the problems of erratic protein supply (i.e. low spring protein content, excess protein from July onwards) that occurs in the grass/clover leys and improve the efficiency of N-utilisation within both organic and low-input systems that rely on clover as the main source of nitrogen. Although including the rapid-growing but short-lived Westerwolds ryegrass in a mixture has the potential to provide high yields of forage in a short time period, the implications in relation to quality, the domination of the legumes in the swards by the grass species and the need to replace the grass has nutritional, financial and environmental implications and a less aggressive grass may be more compatible with the other species.

3.3.2 The potential of whole-crop cereals as a feed when either grown alone or with a legume

Whole-crop cereals can be easily grown in organic systems and make a positive contribution to the annual forage production on many organic dairy farms. Whole-crop cereals provide: (a) a palatable conserved forage that has a higher DM content than the majority of grass + clover silages, (b) a valuable nurse or cover crop for the under sown ley, and (c) a reduced time period between the last grazing or harvest of the previous crop and the start of production of the succeeding crop.

3.3.2.1 The effect of the seed rate on the yield of whole-crop cereals

The standard practice at Ty Gwyn has been to establish spring barley cereal crops at a seed rate of 200 kg /ha unless the crop is being undersown with a grass/legume ley, when a lower seed rate is required to allow the ley to establish without the adverse influence of either shading or species competition from the cereal cover crop. To determine the effect of whether a seed rate of 200 kg/ha leads to optimal crop yields, spring barley was sown in 2004 at 150, 200 and 250 kg/ha and sampled on 21 July when the grains were at the medium dough stage of ripeness. The DM content and DM yields were: 43.1 & 10.5, 44.5 & 10.3 & 42.2% & 13.5 t/ha, respectively. Increasing the seed rate to 250 kg/ha markedly increased yield but slightly reduced DM. At a cost of £450-00 per tonne of organic cereal seed the seed costs per hectare at seed rates of 150, 200 & 250 kg/ha were £67-50, 90-00 & 112-50 per hectare. In terms of the nutritive value for the dairy herd the extra cost of seed was offset by the higher yields crop which also leads to a reduction in the production costs per hectare.

3.3.2.2. The effect raising the cutting height at harvest on the yield and digestibility of whole-crop barley.

A key influence on the performance and efficiency of organic dairy systems is the quality of the forage that is produced for either grazing or conservation. Therefore, any increase in the energy value of whole-crop cereals would be beneficial in improving the quality of the diets and reducing the gap between the cow's energy requirements in early lactation and the total energy supply from the diet. As the most nutritious part of the cereal plant is the grain component, raising the cutting height at harvest to increase the grain to straw (leaf, stem) ratio has the potential to improve the feed quality of the whole-crop cereals, even though the crop is harvested at c.40% DM when the grains are at the soft-dough to cheesy stage rather than at full maturity. Samples of whole-crop barley were cut at 10, 20 and 30 cm above ground level on three dates with seven days between each sampling date. As shown in Table 10 raising the cutting height slightly increased the DM content, reduced the total DM yield and improved the digestibility of the whole-crop barley. The disadvantage of losing yield by increasing the cutting height is compensated for by the improved nutritive quality, a particularly important factor in seasons when adverse climatic conditions lead to a delayed harvest for the grass + clover crops and the ensiling of forages (i.e. silage) of inferior quality.

Table 10. The effect of the cutting height at harvest on the yield and digestibility of whole-crop barley.

	Cutting height (cm):	10	20	30
Cut 1:	DM% of the whole plant	29.6	29.9	30.4
	Yield (t DM/ha)	10.949	9.956	8.793
	Loss of yield (%)	100	90.9	80.3
	Digestibility (%)	68.7	69.5	70.3
Cut 1:	DM% of the whole plant	36.3	37.2	38.2
	Yield (t DM/ha)	11.186	10.327	9.362
	Loss of yield (%)	100	92.3	83.6
	Digestibility (%)	71.9	73.2	75.0
Cut 1:	DM% of the whole plant	37.6	38.5	39.6
	Yield (t DM/ha)	12.041	11.080	10.147
	Loss of yield (%)	100	92.0	84.3
	Digestibility (%)	67.9	69.4	71.2

3.3.2.3 Growing legumes and cereals together to improve the quality of whole-crop cereals

Mixtures of cereals and legumes have the potential to increase the protein content of the harvested forage and via the post-harvest stubble and roots also provide residual nitrogen for the succeeding crop. In previous years vetches grown at Ty Gwyn have shown potential benefits as both the companion species to oats in cereal/legume mixtures and also as both a primary N-fixator and protein feed in grass-based mixtures. As shown in Table 11 both spring barley (variety – Dandy) and spring triticale (variety – Cume) were sown either alone or with English Common vetch at two different seed rates. The spring barley plots were sampled on 21 July when the barley grain was at the soft dough stage and ready for ensiling. The spring triticale plots were later maturing and were sampled on 21 July, 10 August and 19 August when the maturity of the grains were: water ripe seed coat, late milk and early dough, respectively. The yields of spring barley + vetches was higher than from spring barley grown alone, however, in the plots with the later maturing triticale the yield advantages of the mixture compared with triticale grown alone were only shown when the cereal crop had reached the early dough stage of growth. The early maturing barley + vetch mixture led to high production and no problems of lodging. However, in the triticale + vetch plots lodging of the mixtures was recorded due to the later growth pattern of the vetch plants. These results suggest that when the growing of mixtures is being considered, the maturity stages of both the cereal and vetches needs to be similar unless a tall strong-stemmed cereal species (e.g. oats) is grown with the legume. An important factor to consider is that the DM content of the vetch will be consistently lower than that of the companion cereal species, therefore the harvest date of a cereal + vetch crop (depending on the proportion of vetch in the total crop) will be later than for cereals grown alone. Vetches with a protein value of 20-22% significantly increase the protein content and feed value of the whole mixture as the protein of the cereal crop alone will be <11%.

Table 11: The whole plant yields from spring barley and spring triticale crops either grown alone or in a mixture with common vetch

Sampling date	**Crop type**	**Seed rate (kg/ha)**	**DM%**	**Individual crop DM yield (t/ha)**	**Total DM yield (t/ha)**	**% vetch in mixture**
21 July	Barley only	200	38.61	10,302	10,302	0
	Barley	150	37.78	9,663		
	+ Vetch	60	18.64	1,500	11,163	22.1
	Barley	100	36.98	9,576		
	+ Vetch	120	17.24	1,980	11,556	50.1
	Triticale only	200	33.25	9,017	9,017	0
	Triticale	150	33.95	6,939		
	+Vetch	60	16.41	1,973	8,912	13.4
	Triticale	100	29.70	4,580		
	+Vetch	120	15.70	4,600	9,180	17.1
10 August	Triticale only	200	34.08	11,029	11,029	0
	Triticale	150	32.87	7,659		
	+Vetch	60	18.29	1,540	9,199	16.7
	Triticale	100	32.89	4,953		
	+Vetch	120	18.92	6,542	11,495	56.9
19 August	Triticale only	200	38.89	11,003	11,003	0
	Triticale	150	37.11	10,286		
	+Vetch	60	21.97	1,560	11,846	13.2
	Triticale	100	34.96	6,219		
	+Vetch	120	20.33	6,168	12,387	49.7

3.4 Herd performance in the two systems

3.4.1 Composition of the diets for the cows in the two systems

The annual feed inputs for the two systems are shown in Table 12. Although in the early part of the study the standards for organic production allowed the inclusion of 10% non organic ingredients in the diets fed to the cows in the PC system, the decision was made in April 2004 to change to 100% organic diets as the price of organic concentrate feeds had fallen, leading to no extra costs by changing to fully-organic diets. Feeding 100% organic diets also removed concerns in relation to ensuring all feed imported into the system was GM-free should soya beans, for example, be purchased as a suitable protein feed for balancing the diets. In the table below the proportion of organic, home-grown and forage feeds in the total diets fed in the two systems are shown. Due to TB restrictions on selling cull cows from the two systems that led to feed shortages in both systems, extra forage was purchased in the 2003/04 period. In the SS system the low protein content (10-11%) of the cereal grains was balanced by growing and feeding pure red clover silage to ensure the average protein content of the rations did not fall below 16%.

Table 12. Annual feed inputs to the two dairy herds in the systems.

Year:	2002/03	2003/04	2004/05	2005/06
SS system: % organic	100	100	100	100
% home-grown	99.5	93.3	100	100
% forage	95.2	91.5	90.3	94.0
PC system: % organic	96.2	96.2	100	100
% home-grown	80.4	51.7	77.3	81.6
% forage	80.4	77.3	77.3	81.6

A key factor in the management of the SS system was the quantity of grain that could be produced annually and, therefore, the quantity of concentrates that could be fed to the cows during the lactation period (0.329 to 0.666 t/cow). The limitation on the quantity of concentrate feeds (i.e. cereal grains) available for feeding led to the majority of the annual grain harvest being fed during the first 100 days of lactation as this was the critical period in relation to the cow's peak feed energy requirement. Throughout the study the energy level of the diets fed to the cows in the SS system was a limiting factor. The diet had a very high forage content (>90%) and a consistent lack of energy during the early lactation period that led to lower milk protein values and reduced milk persistency during this period of the lactation. The option of increasing the proportion of land allocated for grain production was considered. However, while this strategy would have increased the quantity of concentrates available for feeding and increased the energy density of the diets, there would have been an adverse affect on the total quantity of nitrogen available (primarily from N-fixation by legumes) to ensure satisfactory growth and yields were achieved from the N-demanding crops in the rotation (grasses, cereals etc). Increasing the area allocated to cereal production from 17.5 to 35% would have reduced the N supply by 79% from 99 to 78.5 kg/ha, lowered the stocking density and reduced the average crop energy yield/ha. In the PC system where a key objective was to maximise the output of milk per hectare, a more flexible strategy was implemented in relation to both the quantity of concentrates fed per cow and types of ingredients used in the formulation of the concentrate mix. Concentrates contributed up to 40% of the total ration during the early-lactation period and as shown in Table 13 the quantity of concentrates fed during the lactation was correlated to the daily milk yield of the individual cows, with a higher rate fed during the period of winter housing when lower-energy diets based on silage were fed.

Table 13. The allocation of concentrate feeds during the lactation period to cows in the PC system.

Daily milk yield (litres/cow)	10	15	20	25	30	35	40
Concentrates fed to cows on silage-based diets (kg/day)	2	3	4	5	6	7	8
Concentrates fed to cows on herbage-based diets during the grazing season (kg/day)	0	1	2	3	4	5	6

3.4.2 Herd performance in the two Ty Gwyn systems

Table 14 below shows the physical performance of the dairy herds in the two systems in relation to stocking density, concentrate inputs and the output of milk and milk components. As shown in the table both the average number of cows in the herd and the stocking density in the SS system was consistently lower during the project than in the PC system due to three factors: (a) the requirement to allocate of land for growing cereal grain crops, (b) the feeding of diets with a high forage content, and (c) the implications of achieving a high level of self sufficiency which led to more volatility in feed supplies due to seasonal climatic variations that influenced both crop yields and nutritive quality of the diets that were fed. In both systems the higher stocking densities recorded in 2002/03 were due to the restrictions on moving cows from the farm due to Tuberculin tests proving inconclusive for a number of months. While the stocking density of the PC system was markedly higher than in the SS system, if an allowance is included for the area of land required for the production of the purchased concentrate feeds (i.e. growing winter barley and triticale in a 1:1 land area ratio) then the stocking density in the PC system would be reduced from 1.96, 1.68, 1.68 & 1.54 to 1.27, 0.99. 0.99 & 0.82 cows/ha. Therefore, inclusion of the total land area required for sustaining the PC system would result in a stocking density lower than in the SS system. In the SS system the limited quantity of concentrate feeds (i.e. cereal grains) available annually led to the feeding of the majority of the annual grain harvest in the first 100 days of lactation as this is the critical period in relation to the cow's peak feed energy requirement. In the PC system where a key objective was to maximise the output of milk per hectare, a more flexible strategy was implemented in relation to both the quantity fed per cow and types of ingredients used in the formulation of the concentrate mix. Concentrates contributed up to 40% of the total ration during the early-lactation period with an average of 1.544 tonnes of concentrates fed per cow i.e. 1.025 t higher than in the SS system or nearly three times the total quantity per annum.

The incidence of liver fluke had a major impact on the performance of the two herds, as shown by the lower milk output (both per cow and per hectare) in the 2003/04 period. The predicted targets for the rolling average milk yield per cow and quantity of milk fat + protein components were a minimum of 5,000 litres and 361 kg (SS system) and 6,000 litres and 433 kg (PC system), respectively. The minimum targets were achieved in the SS system in the final two years of the project and in 3 out of 4 years in the PC system. It is concluded that but for the incidence of liver fluke the targets would have been met throughout the project.

Table 14. The physical data on the performance of the herds in the two systems

	2002/03	2003/04	2004/05	2005/06*
SS system				
Stocking density (Livestock units/ha): – whole area	1.28	1.12	1.15	1.08
- forage area only	1.56	1.34	1.40	1.32
Average number of cows in the herd	39	34	35	33
Quantity of concentrate feeds (t/cow)	0.329	0.579	0.666	0.502
Annual milk output (litres):				
Milk output/ha	6,086	4,817	6,695	5,931
Rolling milk yield/cow	4,755	4,301	5,822	5,492
Annual milk yield/cow	6,022	5,192	6,609	6,492
Annual quality-corrected milk yield/cow	6,054	5,481	6,537	6,326
Rolling annual milk production from forage	4,087	3,158	4,441	4,436
% of milk produced from forage	86.0	73.4	76.3	80.8
Average milk fat concentration (%)	4.12	4.31	4.04	3.87
Average milk protein concentration (%)	3.22	3.39	3.18	3.24
Average yield/cow of fat + protein (kg)	349	331	420	390
Rolling average somatic cell count ('000 cells/ml)	192	336	247	339
PC system				
Stocking density (Livestock units/ha)	1.96	1.68	1.68	1.54
Average number of cows in the herd	55	47	47	43
Quantity of concentrate feeds (t/cow)	1.341	1.562	1.531	1.743
Annual milk output (litres):				
Milk output/ha	12,532	8,743	11,090	10,487
Rolling milk yield/cow	6,596	5,204	6,601	6,810
Annual milk yield/cow	8,086	5,893	7,387	7,986
Annual quality-corrected milk yield/cow	8,080	6,082	7,188	7,820
Rolling annual milk production from forage	3,510	1,843	3,276	3,021
% of milk produced from forage	53.2	35.4	49.6	44.4
Average milk fat concentration (%)	4.05	4.10	3.87	3.87
Average milk protein concentration (%)	3.25	3.43	3.23	3.28
Average yield/cow of fat + protein (kg)	481	392	469	487
Rolling average somatic cell count ('000 cells/ml)	271	298	270	247

* Calculated from the data fro the October 2005 to June 2006 period

3.4.3. The effect of concentrate costs and milk price changes on the financial margins

During the study the price of purchased feeds was lower and the variation in price less in the PC system when compared with the concentrates fed in the SS system (Table 15). The financial margins per litre of milk were higher in the SS system due to the relatively low quantity of concentrates fed, particularly in Year 2 when the adverse effects of liver fluke severely reduced the efficiency of feed utilisation in the PC system. However, with the exception of Year 2 the financial margins per cow were significantly higher in the PC system due to the increased efficiency of feed conversion into milk, including a greater proportion of the nutrients being used for milk synthesis rather than body maintenance.

Table 15. The concentrate feed costs and financial margins for the dairy herds in the two systems.

	2002/03	2003/04	2004/05	2005/06*
SS system				
Average price of concentrate feeds (£/tonne)	222	198	174	225
Average price paid by the milk buyer (pence)	21.18	22.46	21.79	25.26
Financial margin (excluding concentrate feed costs):				
- pence/litre of milk	19.63	19.64	19.52	21.65
- £/cow	934	845	1136	1189
PC system				
Average price of concentrate feeds (£/tonne)	154	154	160	173
Average price paid by the milk buyer (pence)	21.18	22.46	21.79	25.26
Financial margin (excluding concentrate feed costs):				
- pence/litre of milk	18.02	14.82	17.99	19.23
- £/cow	1188	771	1187	1310

* Calculated from the data fro the October 2005 to June 2006 period

3.4.4 Milk persistency during the lactation of heifers in their first lactation

Data analysis and regression equations (using GENSTAT 5 software package) were conducted to determine differences between the systems in the effect of different levels of feed energy supply on the milk persistency of heifers during their first lactation. Inadequate feed energy levels in the SS system led to a lower milk persistency during lactation and a decline of 0.31 kg/week compared with 0.28 kg/week in the PC system, where the energy density of the diets was consistently higher. Re-modelling the data using a standard correction factor (fat% - 4.0, protein% - 3.3) for the milk solid concentration increased the difference between the two groups: SS 0.25 kg/week, PC 0.20 kg/week. The increased decline of milk persistency in the SS system also reduced the efficiency of feed conversion into milk. The sharpest decline in the milk yield of the cows in the SS system occurred during the early lactation period and indicates a lack of energy in the diet and a failure of the animals to provide sufficient extra energy via the mobilisation of body tissue which naturally occurs in the majority of dairy cows during this period of the lactation.

3.4.5 The efficiency of the conversion of feed energy into milk

The efficiency of the conversion of total feed energy into milk was calculated during the study and the results are shown in Table 16 below. The conversion of feed energy was consistently higher in the PC system and reflects the higher milk yields per cow and, therefore, the greater proportion of feed energy that is utilised for the synthesis of milk rather than maintenance.

Table 16. The efficiency of the conversion of feed energy into milk (%).

SS system		2002/03	2003/04	2004/05	2005/06
MJ/cow:	Dietary forage energy input	88,149	85,877	94,766	86,802
	Dietary concentrate input	6,699	7,984	8,867	7,110
	Milk energy output	26,412	24,937	30,343	27,946
	Efficiency of feed conversion into milk (%)	27.8	26.6	29.3	29.8
PC system		2002/03	2003/04	2004/05	2005/06
MJ/cow:	Dietary forage energy input	66,315	69,308	80,145	81,906
	Dietary concentrate input	17,254	19,191	15,135	19,010
	Milk energy output	33,301	34,279	32,438	33,994
	Efficiency of feed conversion into milk (%)	39.8	38.7	34.0	33.7

3.5 Herd health and reproductive performance in the two Ty Gwyn systems

3.5.1. Herd health

In evaluating the effect of the systems on the incidence of specific health problems (Table 17) it is important to note that the information is from a relatively small number of cows in each system when compared with the comprehensive data sets that has been included in some published reports on the health status of UK dairy herds. The main health problem in both herds was liver fluke that occurred in February 2003 when two cows died suddenly without showing any symptoms prior to death. Following examination the veterinary surgeon confirmed the whole herd was affected. All cows were immediately drenched with a flukocide, with further treatment given at 6-monthly intervals. The occurrence of liver fluke in both systems led to unthrifty cows, low silage intakes, iodine deficiency, reduced milk yields and reduced reproductive efficiency. The higher rate of cows failing to conceive was attributed by the veterinary surgeon to iodine deficiency and all cows were given a slow-release mineral bolus that contained primarily iodine but also small quantities of selenium and cobalt. Higher rates of clinical mastitis and lameness during the study are attributed to a reduced immunity to disease as a result of the adverse effects of liver fluke. The incidence of lameness was also due to the poor physical conformation of a number of cows within the two systems and the occurrence of digital dermatitis which has become a major problem in many UK dairy herds. Despite the feeding of diets with a high energy density and optimal energy to protein balance in the PC system the cows did not appear to have an improved immunity to disease compared with those in the SS system. With the exception of the occurrence of milk fever in both systems, which was similar to the levels reported in commercial herds, there were no clinical cases of ketosis or hypomagnesaemia recorded. However, high fat to protein ratios (>1.4) recorded in the milk from cows during early lactation showed sub-clinical ketosis to be a problem with a number of cows, particularly in the SS system. Despite the grazing of many clover-rich swards during the study no cases of bloat were recorded and this was attributed to the practice of ensuring a consistent quantity of herbage was available daily during the grazing season to avoid the risk of cows rapidly eating a high-clover diet. With the exception of liver fluke, there were no other parasitic problems recorded in the two system.

Table 17. The incidence of specific health problems recorded from the cows in the two systems.

Health problem:	SS 2002/03	2003/04	2004/05	PC 2002/03	2003/04	2004/05
Lameness	11	13	39	14	26	37
Clinical mastitis	33	38	34	41	45	37
Abortion	9	4	2	3	2	0
Digestive upset	7	4	7	4	0	2
Infertility	26	27	11	34	17	12
Milk fever	7	13	7	4	7	7
Retained foetal membranes	13	0	5	6	3	8
Metritis	30	40	20	35	22	23
Injury	7	4	7	10	0	13

During the study all the lactating cows were inseminated, with a bull used to naturally serve those cows failing to conceive after three inseminations. The cows in the herd were predominantly Holstein-Friesian and sired by bulls bred and reared in intensive conventional systems. To better match the genetics of the herd with the type of diets being fed, particularly the very high forage diets in the SS system, the cows were inseminated with semen from New Zealand bulls that had a high proportion of Friesian genetics. All heifers were naturally served by a beef bull to minimise the risk of problems when cows gave birth, including both Hereford and Aberdeen Angus bulls. However, irrespective of the sire and careful management of the diets in the growing heifers, some problems at calving were recorded.

3.5.2 Reproductive performance

Table 18 shows the reproductive performance of the cows in the two systems during the study. Prior to the start of the study the annual pregnancy rate of the PC herd had been consistently higher (90%) compared with 83% in the SS system, however, during the current study the adverse effects of the liver fluke problems led to a sharp reduction in the number of cows becoming pregnant. However, by 2004 the pregnancy rates in both systems had improved to acceptable levels, meeting the pre-defined target of achieving an 85-90% pregnancy rate. Following the reduction in the number of cows becoming pregnant the culling rates increased in both systems and led to a small number of in-calf heifers being purchased, in addition to those already being reared within the systems.

Table 18. The annual reproductive performance of cows in the two systems.

	SS 2002/03	2003/04	2004/05	PC 2002/03	2003/04	2004/05
Number of serves/pregnancy	2.64	1.90	2.22	2.07	2.70	2.40
Number of cows conceiving to 1st service	45.5	61.9	59.3	44.4	60.0	50.0
Number of days to conception:						
Mean	147.0	91.3	126.9	149.1	83.4	118.5
Median	132	82	98	131	83	98
Maximum	291	217	342	289	127	336
% of cows becoming pregnant	71.0	84.0	90.0	55.1	57.2	85.7
Culling rates (%)	15	19	27	11	33	33

3.5.3 Veterinary investigations to monitor the health status of the cows in the two Ty Gwyn systems

The maintenance of herd health status, high milk quality and satisfactory conception rates were key aims in both the dairy systems to ensure they remained financially viable. Achieving these aims was dependent on the quality of the diets fed particularly during the early lactation period, with both energy and mineral status important factors. Following the outbreak of liver fluke problems the decision was made on the advice of the veterinary surgeon to further investigate the health status of cows in both of the systems. Blood samples were taken during the early lactation period from a group of cows in each system with a sub-group also sampled again in mid-lactation (Table 19).

Table 19. The results from blood samples taken from s sub-group of cows in each system to determine both the energy and mineral status of cows in the two systems.

System, Cow number	Days From calving	Energy status Betahydroxybutyrate (mmol/l) Normal range 0-1.2	Milk fat to protein ratio (Values > 1.3 = low energy)	Copper (mmol/l) Normal range 9-19	Selenium (GSH-Px U/ml)* Normal values >30
16-04-03					
SS 1718	71	0.41	1.31 LOW	14.6	23.0 LOW
SS 1725	57	0.51	1.34 LOW	16.5	35.2
SS 2387	35	0.48	1.13	11.4	43.9
SS 2390	30	0.48	-	16.7	33.4
SS 2391	34	0.69	1.27	14.8	41.8
SS 2411	57	0.56	1.38 LOW	13.3	39.3
SS 2808	17	0.54	1.33 LOW	22.5	48.3
SS 2831	16	0.41	1.31 LOW	22.1	38.0
SS 9348	16	0.53	1.11	19.8	37.8
PC 1714	66	0.52	1.30	12.4	-
PC 1715	76	0.41	1.27	15.2	52.5
PC 2113	33	0.48	1.19	15.5	14.9 LOW
PC 2382	19	0.45	0.94	16.8	41.0
PC 2405	75	0.68	1.30	19.2	45.3
PC 2475	35	0.57	1.11	12.1	42.0
PC 2824	24	0.25 LOW	1.37 LOW	15.4	19.2 LOW
PC 2839	50	0.57	1.58 LOW	18.7	77.7
PC 9527	52	0.57	1.11	18.9	48.7
20-06-03					
SS 1718	135	0.36	1.29	10.8	19.1 LOW
SS 2387	99	0.43	1.18	11.7	40.7
SS 2391	98	0.52	1.48 LOW	11.9	42.8
SS 2411	121	0.45	1.55 LOW	10.7	45.8
SS 2808	81	0.56	1.36 LOW	12.4	46.5
PC 1714	130	0.44	1.25	11.9	51.9
PC 2382	83	0.38	1.10	11.1	33.7
PC 2405	139	0.36	1.44 LOW	21.2	63.8
PC 2475	99	0.68	1.25	12.8	48.3
PC 2839	114	0.49	1.43 LOW	19.0	101.1

- GSH-Px is Glutathione Peroxidase, the enzyme containing selenium

The samples were taken on 16 April (cows in both systems being fed on silage-based diets prior to turn-out) and 20 June 2003 (cows in both systems grazing herbage, no supplementation fed to the SS group) and analysed by the Veterinary Laboratories Agency to determine their energy, copper and selenium status. The results show a low selenium status in a few of the cows during early lactation and similar energy status in both groups despite the feeding of higher energy diets in the PC system.

Cystic ovaries were a problem with a number of cows in both systems during this period, contributing to the problems of both delayed conception and failure to conceive. An increase in cystic ovaries during 2003 was also reported in many other UK herds (Laven, 2004).Published literature has shown cystic ovaries to occur predominantly in the winter housed period and the cause may be related to nutrition (particularly high starch diets being fed immediately post-calving) or stress. While wheat grains with high starch content were fed to cows in the PC system, the starch content of the diets in the SS system was low. Therefore, nutrition was unlikely to be the cause and stress, due to the adverse effects of liver fluke infestation, was the more likely reason for the problem. As shown in Table 20 below further investigation of some of the problem cows showed low blood iodine levels (as determined by serum thyroxine analysis) in a number of the cows. The normal range for serum thyroxine in cattle is 50-150 n.mol/litre. Normally the availability of iodine in on-farm feeds is higher in coastal areas and few problems of deficiencies recorded (Underwood and Suttle, 1999). However, at Ty Gwyn the iodine levels in the herbage were very low and in the view of the veterinary surgeon this is likely to have been a key contributory factor to the problem.

Table 20. The results from blood samples taken from a sub-group of the cows in the two systems to determine the serum thyroxine concentrations as an indicator of the cow's iodine status.

Cow number	System	Serum thyroxine (n.mol/litre)	Cow number	System	Serum thyroxine (n.mol/litre)
2411	SS	48.2	5376	PC	38.4
2388		37.7	2423		39.8
2417		48.7	58		50.0
2399		46.9	309		71.0
	Mean:	45.4		Mean:	49.8

3.5.4 Longevity and the annual calving pattern

No differences were recorded between the systems in the longevity of cows within the two herds, with an average of 2.7 lactations recorded in both systems, both at the start and finish of the study. The culling rate of cows from the two systems increased sharply during the study and was primarily a result of the failure of a number of cows to become pregnant despite the use of both artificial insemination and natural service by a bull. Other reasons for culling included problems associated with lameness and high somatic cell counts. Higher culling rates increased the costs of milk production in both systems as the calculation of the cost of replacing animals within the two systems shows that a first-lactation heifer entering the herd costs £670 to rear from birth to 2-years old, with a loss of milk income of £250 during the first lactation and the costs only partly offset by the c.£300 received for each cow culled from the systems. The magnitude of the loss is similar in both systems as the yield differences between a first-lactation heifer and a multi-lactation cow are similar despite the markedly higher milk yields per cow recorded in the PC system.

The objective in both systems was to aim to calve the cows in the Feb-April period to ensure optimal milk production from grazed herbage when forage quality was high and also to efficiently use the cheapest feed available to the cows during the year. However, following the occurrence of liver fluke that reduced the reproductive efficiency of the herds, there was an increase in the number of days from calving to conception with some cows in the herd, leading to a year-round calving pattern. Only in the final year, when the health problems were overcome, was a predominantly spring-calving pattern established.

3.6 Nutrient budgets for the two Ty Gwyn systems

The nutrient budgets in each system were calculated annually in April at the end of the winter period of housing (Table 21). The main inputs to the budgets were N-fixation by legumes, the imported concentrates (PC system only), purchased bedding, seaweed meal and nutrient deposits from rainfall. The main output was milk produced by each herd of cows and also the animals culled from the systems. The major factors influencing the nutrient budgets were the proportion and total yield of legumes produced annually in the grazed and conserved swards and the influence of health problems (i.e. liver fluke) on the annual milk output per hectare, ratio of lactating to non-lactating animals and the reproductive efficiency within the herd. The need to purchase extra forage for feeding (PC system – Year 2) and replenishing silage stocks (SS system – Year 3) due to Tuberculin restrictions on the export of cull animals from the systems decreased the proportion of the total N-input from fixation by the legumes and also increased the K-surplus in the PC system due to the larger quantities of forage that were imported into the system. Despite the importation of significant quantities of concentrates into the PC system, in three of the four years there was an annual deficit of phosphorus as the high milk production, both per cow and per hectare led to the exporting of large quantities of the mineral from the system. In both systems the efficiency of N-utilisation for milk production increased in Years 3 and 4 due to the improved efficiency of milk production and a lower total input of nitrogen via N-fixation by legumes. The difference between the systems in the annual contribution of N-fixation by legumes to the total N-input resulted primarily from the importation of concentrates into the PC system.

Table 21: The annual 'whole-system' nutrient budgets and efficiency of N-utilisation for milk production for the two systems.

	N		P		K		Proportion of Total N-input from fixation	N-utilisation for milk production (%)
	kg/ha	LU/ha*	kg/ha	LU/ha	kg/ha	LU/ha		
SS system:								
Year 1	+90.0	+65.5	-4.0	-3.2	-3.0	-2.4	95.4	20.5
Year 2	+61.9	+51.1	-3.8	-2.5	-3.7	-1.0	94.9	20.0
Year 3	+51.0	+40.8	-4.9	-3.9	-2.5	-2.0	85.7	31.9
Year 4	+44.8	+35.8	-5.9	-4.7	-6.2	-5.0	93.6	32.3
PC system:								
Year 1	+140.0	+73.8	0	0	+5.0	+2.6	67.7	24.6
Year 2	+156.0	+95.1	+8.6	+5.3	+52.0	+31.7	43.2	19.3
Year 3	+106.7	+68.4	-2.7	-1.7	-1.9	-1.2	64.8	30.8
Year 4	+91.4	+58.6	-2.4	-1.6	+3.5	+2.2	52.8	32.5

*LU = Livestock units

3.7 Comparison of the two Ty Gwyn systems with the performance of six stakeholder commercial organic dairy systems

In Table 22 below the physical parameters and average performance of both the six stakeholder organic dairy farms (ST1-6) in England and Wales and two Ty Gwyn systems (SS, PC) during the 3-year period is shown in the table below. The lowest and highest values recorded in the eight systems for the key individual parameters are shown in a bold fonts. Major differences were recorded between the farms including contrasting cropping strategies, a range of dairy breeds and a diversity of management strategies ranging from extensive systems producing all feed within the system to the more intensive systems reliant on the importation of high quantities of concentrate feeds. As shown in the table there does not appear to be a relationship between the annual rainfall and the length of the grazing and housing periods. The farm with the lowest stocking density recorded the highest total milk yields and yields from forage. In relation to the level of concentrate feeding, the lowest and highest quantities of concentrates fed were in the two Ty Gwyn systems. However, the concentrate inputs in the SS system were only marginally lower than in the ST1 system, with both recording the highest proportion of milk from forage through efficient forage utilisation and achieving their stated objective of maintaining a high level of self sufficiency. With the exception of the spring-calving herd in the PC system, the lowest proportion of milk from forage was recorded in the three systems where the herd calved all the year round. N-utilisation from forage was also below 20% in two of these systems (ST4, ST5) suggesting that for a significant number of cows in the herd a year-round calving pattern does not ensure the optimal balance between the quality of feeds and the cow's high nutrient requirements during the early lactation period and reducing the efficiency of feed utilisation. The large variation between systems in the proportion of nitrogen that was converted into milk is similar to the results from other studies. In five of the systems there was an annual deficit in the phosphorus budgets, with an annual deficit of potassium only recorded in one system (i.e. Ty Gwyn SS system).

Table 22. The physical details and performance data from the six stakeholder farms (ST1-ST6) AND TWO Ty Gwyn systems (SS, PC) during the study.

System:	ST6	ST4	SS	ST5
Primary soil type	Heavy clay	Medium loam	Loam over clay	Loam over sandstone
Annual rainfall (mm)	850	1,067	1,140	1,067
Breed(s) of dairy cattle*	Mainly H, some MRI, N, SD & S	BF, H	HF	Mainly BF, some A, BS, G, MRI, S
Grazing season period (months)	5.5	8	7	7
Calving season period	85% Autumn, 15% Spring	Year round	Spring	Year round
Crops and leys grown:				
1. Forage crops: Multi-species developing	N	N	N	N
leys	Y	Y	Y	Y
Short-term leys	Y	Y	Y	Y
Medium-term leys	Y	Y	Y	Y
Permanent pastures/leys >7 years	N	N	N	Y

Whole-crop cereals	N	Y	N	N
Whole-crop cereals + legumes	Y	N	N	N
Field beans	N	N	N	N
Fodder beet				
2. Grain crops:	Y	Y	Y	Y
Wheat/Oats/Barley	Y	N	N	N
Peas/Field beans/Lupins				
3. Non-agricultural crops:	N	N	N	Y
Potatoes/Brassicas				
Herd performance:				
Stocking density (LU – Livestock units/ha)	**0.97**	1.05	1.26	1.27
Calving index (days)	**416**	377	399	365
Concentrate inputs (t/cow)	0.735	0.750	**0.498**	1.000
Proportion of milk output from forage (%)	72.4	58.6	79.7	56.2
Milk output (litres): Total annual	**7,382**	**5,350**	5,901	6,210
yield/cow	**6,194**	**4,296**	5,062	5,114
Total rolling average yield/cow	5,950	**4,576**	5,748	6,337
Total annual yield/ha	**5,338**	**3,104**	4,441	3,498
Total annual yield from forage/cow	**4,481**	**2,522**	3,800	2,880
Total rolling average yield from forage/cow	3.92	**3.87**	4.18	4.25
Milk fat concentration (%)	3.37	**3.10**	3.28	3.35
Milk protein concentration (%)	22.5	**12.5**	20.0	16.5
N-utilisation for milk production				
Nutrient balances (3-year average):				
Annual nutrient Surplus/Deficit (kg/ha): N	**+82.5**	+130.9	+84.7	+118.3
P	**-3.8**	-1.4	-3.7	-1.3
K	+6.3	+2.1	**-0.2**	+35.4
Annual nutrient Surplus/Deficit (kg/LU): N	+92.7	**+123.2**	+64.0	+95.2
P	**-4.2**	-1.3	-2.9	-1.1
K	+5.0	+4.5	**+0.2**	**+28.4**

* Breeds of dairy cows: A = Ayrshire, BF = British Friesians, BS = Brown Swiss, G = Guernsey, H = Holstein, HF = Holstein-Friesian, MRI = Meuse Rhine Issel, N = Normande, NZ = New Zealand Friesians, SD = South Devon, S = Shorthorn.

System:	ST2	ST1	PC	ST3
Primary soil type	Silty clay loam	Sandy loam	Loam over clay	Silty loam over gravel
Annual rainfall (mm)	1,016	737	1,140	850
Breed(s) of dairy cattle*	G	Mainly NZ, A, MRI, N, MRI	HF	HF
			7	
Grazing season period (months)	6	7	Spring	10
Calving season period	Year round	Nov-March		Feb-April
Crops and leys grown:				
1. Forage crops: Multi-species developing	N	N	Y	N
leys	Y	Y	Y	N
Short-term leys	Y	Y	Y	Y
Medium-term leys	Y	Y	Y	Y
Permanent pastures/leys >7 years	Y	Y	N	Y
Whole-crop cereals	N	Y	N	Y
Whole-crop cereals + legumes	N	N	N	N
Field beans	N	Y	N	N
Fodder beet				
2. Grain crops:	N	N	N	N
Wheat/Oats/Barley	N	Y	N	N
Peas/Field beans/Lupins				
3. Non-agricultural crops:	N	N	N	N
Potatoes/Brassicas				
Herd performance:				
Stocking density (LU – Livestock units/ha)	1.36	1.53	1.67	**1.92**
Calving index (days)	380	377	396	**363**
Concentrate inputs (t/cow)	1.29	0.450	**1.452**	0.515
Proportion of milk output from forage (%)	53.3	**79.8**	**44.3**	74.7
Milk output (litres): Total annual	7,069	6,258	6,990	5,705
yield/cow	5,803	5,108	5,903	4,751
Total rolling average yield/cow	7,801	7,761	**10,949**	9,340
Total annual yield/ha	3,775	4,897	3,209	4,308
Total annual yield from forage/cow	3,099	3,998	2,677	3,602
Total rolling average yield from forage/cow	**4.70**	4.43	3.99	3.92
Milk fat concentration (%)	**3.52**	3.23	3.33	3.24
Milk protein concentration (%)	21.5	21.0	21.6	27.0
N-utilisation for milk production				
Nutrient balances (3-year average):				
Annual nutrient Surplus/Deficit (kg/ha): N	+103.0	+119.6	**+161.6**	+107.3
P	0	-2.7	+4.9	**+5.4**
K	+16.7	+22.2	**+32.6**	+5.5
Annual nutrient Surplus/Deficit (kg/LU): N	+76.7	+76.6	+94.4	**+54.4**
P	0	-1.7	**+3.0**	+2.8
K	+12.5	+14.4	+19.6	+5.5

* Breeds of dairy cows: A = Ayrshire, BF = British Friesians, BS = Brown Swiss, G = Guernsey, H = Holstein, HF = Holstein-Friesian, MRI = Meuse Rhine Issel, N = Normande, NZ = New Zealand Friesians, SD = South Devon, S = Shorthorn.

The data collected over the 3-year period from the Ty Gwyn systems and stakeholder farms was pooled and regression equations calculated to determine the relationships between the different herd performance indicators. All the physical measurements were recorded from the two Ty Gwyn systems and stakeholder farms, with the exception of the proportion of clover and total crop yields on the stakeholder farms where published figures have been used in the calculations. Therefore, as published rather than actual values have been included for the stakeholder farms the statistical significance level of the individual regression equations has not been included in the table below. The results show that for every 100 kg concentrate input the proportion of milk produced from forage declined by 3.27% units as the efficiency of the conversion of forage into milk declined. Increasing concentrate inputs by 100 kg per cow only increased the rolling milk yield by 107 kg, resulting in a low efficiency of feed energy conversion into milk energy. Dairy systems with higher stocking densities had reduced ‘farm-gate’ nitrogen surpluses, with every 0.1 increase in the stocking density correlated to a decrease of 3.71 kg/ha in the N-surplus. However, it is important to note that these systems with higher stocking densities were reliant on imported feeds grown elsewhere to maintain the system.

Table 23. The linear relationship between performance parameters from the eight organic dairy systems.

x	y	Linear regression
Concentrate inputs (t/cow)	% of milk produced from forage	y = 92.514 - 32.734x s.e. 5.41
Concentrate inputs (t/cow)	Rolling average milk yield (kg/cow)	y = 1070.5x + 4398.8 s.e. 737.44
Stocking density (Livestock units/ha)	Farm-gate nitrogen surplus (kg/Livestock unit)	y = 136.00 – 37.141x s.e. 20.58
Stocking density (Livestock units/ha)	Efficiency of N-utilisation for milk production	y = 7.5509x + 9.4161 s.e. 4.12
N-surplus (kg/Livestock unit)	Efficiency of N-utilisation for milk production	y = 33.098 – 0.1503x s.e. 3.75

Section 4. Discussion

The results from the project provide detailed and quantitative data on the performance of two contrasting organic dairy systems. As the two systems are located within one site the comparative measurements between the systems have not been compounded by other factors including differences in geographical location, climatic conditions and soil type. By comparing the two systems with six commercial stakeholder farms the project has provided information on a range of contrasting systems with different soils, climatic conditions and management strategies. The herd performance results recorded in the comparative study between the two systems was affected by the outbreak of liver fluke disease, which had an adverse effect on herd performance, efficiency of feed conversion into milk, animal health and reproductive efficiency during the early part of the project.

The work at Ty Gwyn has shown that the SS system that was based on a high level of self sufficiency and the establishment of a more complex crop rotation, is more complicated to manage but is not only practical in relation to the physical management of the system but also leads to improved forage utilisation, a reduced annual ’farm’gate’ N-surplus and a more sustainable system. However, the system is less flexible than one based on a forage-only cropping strategy and importation of concentrate feeds into the system (i.e. PC system), as the quantity and quality of feed available for formulating the diets for the dairy herd are more limited and influenced by seasonal climatic conditions, the annual crop yields and the need to grow sufficient legumes as either mixed or monoculture crops to provide nitrogen via fixation for crop growth and feed protein. The variation in the annual crop yields was clearly illustrated by the wide range in the annual grain yields produced from individual cereal species. The results from the study have shown clearly that feed energy was a critical factor in the management of the system in relation to not only herd performance but also health status and reproductive performance. A key driver in the SS system was the limited quantity of concentrates (e.g. cereal grains) that were available for feeding to the cows, which influenced not only herd performance in relation to milk output (both per cow and per hectare) but also had an adverse effect on milk persistency during lactation, milk quality and reproductive performance. The option of increasing the area of land allocated to grain production from 17 to 34% would have improved the energy density of the diets but led to a deficit of total nitrogen in the system for growing the N-demanding species (i.e. grass and cereal species). The option of including fodder beet as a potential high-energy forage crop was evaluated but the results showed that the positive benefits of the increased feed energy were balanced by a significant increase in feed costs. The other alternative of changing from growing and combining cereal crops to growing and ensiling only forage was considered. However, while this option would have overcome any problems in the N-supply within the system being too low, the quality of the forage would be likely to reduce rather than enhance the energy density of the diet.

The results from the study showed that the PC system based on purchased feeds maintained a markedly higher level of output, including stocking density and milk production per hectare, by importing and feeding a much higher level of concentrates compared with the SS system, leading to more balanced diets and improved milk persistency during lactation. The conversion of feed energy into milk was also markedly higher compared with the results from the SS system, due to the increased proportion of nutrients being utilised for milk production. However, the results also show that if the area that is required to produce the purchased concentrate feeds is also included within the calculations for the whole system, the stocking density would be lower than in the SS system and the milk output per hectare sharply reduced. The system is also more vulnerable to market forces in relation to both the supply and price of concentrate feeds, including imported feeds into the UK. The strategy of changing from a crop rotation to the establishment of multi-species leys has already shown benefits in terms of reducing forage costs and providing leys that have the potential to more easily adapt to climatic changes and variations in the soil type and profile within individual fields. These leys are in the early stages of their productive life and are still undergoing botanical changes.

Although the two systems at Ty Gwyn were based on contrasting strategies in relation to nutrient sources, there were no significant differences between the systems in either soil or herbage mineral concentrations. Only small differences were recorded between the systems in the yields from the white clover-based leys and permanent pastures and also the proportion of clover in the total yield. Although the average crop energy yield per hectare was lower in the SS system this is attributed to the difference in the systems in the cropping strategy (i.e. growing cereal grain crops only in the SS system) rather than the effect of the management practices within the systems. To date there have been no indications that the difference between the system in the annual ‘farm-gate’ nutrient budgets has affected crop yields or the incidence of specific animal disorders.

A number of field evaluations were carried out during the study with the objective of improving the quality of the crops produced in the SS system. Mixtures formulated to provide rapid forage production were shown to have the potential to provide not only extra feed during a short growing period but also the opportunity to overcome the problem of erratic protein supply by having a succession of legumes contributing to the supply of forage during the growing season. Further work showed the benefits of either increasing the cutting height at harvest of cereal crops or growing a cereal + legume mixture to improve the nutritive quality of cereal crops grown for forage rather than grain production.

With the exception of the incidence of liver fluke in both systems, the animal health data recorded during the study did not show any major differences between the systems, with the incidence of both lameness and clinical mastitis higher than in the initial period when the systems were being established in the 1998/01 period. As shown in the 2004/05 period when the problems of liver fluke had been controlled, the reproductive efficiency of the cows in the PC system was higher compared with the results recorded in the SS system.

The longevity of the Holstein-Friesian cows in both systems was relatively low and while infertility was the major reason for culling cows from the systems, other factors including poor conformation, lameness and high cell counts also led to cows being sold.

The comparison of the Ty Gwyn systems with six Stakeholder farms has provided information from a range of organic dairy systems that are representative of the different types of organic dairy systems in the UK. The performance of the systems varied markedly, including the level of self sufficiency that could be achieved without a reliance on the importation of significant quantities of nutrients via purchased concentrates and also the efficiency of the conversion of nitrogen into milk. The results show clearly that a diversity of management strategies can lead to a viable system in relation to achieving an acceptable output from the system, however, within some systems there is considerable potential to further improve the efficiency of the system including nutrient utilisation.

The study has provided comprehensive information on the main parameters that influence the performance and efficiency of organic dairy systems, identified areas in which the limitations of the individual system are apparent (e.g. supply and influence of feed energy) and evaluated new strategies for improving the systems (i.e. new crops and seed mixtures). The results from the study provides qualitative information on the management of contrasting systems while also contributing practical information for improving organic systems on commercial farms.

The results from the study have provided comprehensive information on a wide range of the key factors that influence the performance and output from the two systems. The results have also highlighted both the benefits and limitations of the two systems in relation to management issues, cropping strategies, herd health as well as highlighting the importance of taking a 'whole-system' approach rather than just looking at just individual components of the systems in isolation. The results provide a sound basis for extending the work into a combined 'integrated' approach that considers both the agricultural and environmental impact of these systems, including conducting a modelling exercise. The results from the study have a practical application for UK organic dairy farms and information can be readily extracted from the results to provide for example technical guides to aid farmers in the management and development of their systems. The Project Leader has been responsible for regularly presenting the results from the study at technical workshops and farmer meetings in England and Wales and also to visitors to the IGER Ty Gwyn organic dairy farm. In addition the results have been used for Farming Connect-funded farm meetings organised by the IGER Grassland Development Centre team.

References to published material

9. This section should be used to record links (hypertext links where possible) or references to other published material generated by, or relating to this project.

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Chapter 9. Handbook of organic food safety and quality (Due to be published by Woodhead Publishing in late 2006)