Session 6
System Projects

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RESEARCH INTO AND DEVELOPMENT OF INTEGRATED FARMING SYSTEMS FOR LESS-INTENSIVE ARABLE CROP PRODUCTION: PROGRESS 1989-1994

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ABSTRACT

The LIFE project is an interdisciplinary research study at IACR Long Ashton designed to address, exploit and integrate interactions of farming system components, holistically, and to provide the technology for economically viable, ecologically acceptable and environmentally benign production systems. The first 5-year cycle was completed at harvest 1994.

Over the 5-year period, adoption of less-intensive strategies based on integrated technology reduced overall yields of wheat and oilseed rape by up to 18%, and yields of barley and oats by 11%. Nevertheless, production costs were also reduced by 32% and overall profitability was maintained. Within this period, substantial reductions (kg ai ha^{-1}) in applied nitrogen (36%), herbicides (26%), fungicides (79%) and pesticides (78%) have been obtained over standard farm practices designed to reflect current arable crop production strategies. Data are presented on innovative strategies and decision making processes, and their implementation in two commercial "Demonstration Farms" in south-west England.

INTRODUCTION

The development and implementation of more environmentally benign, sustainable production systems is being increasingly recognised as the long-term objective for arable crop production systems. This will require a gradual and stepwise transition, taking on board new opportunities created by science and technology, in order to provide a more rational and balanced approach to economically sound agricultural production, aimed at harmony between agriculture and the environment. Most farmers are unlikely to change their practices radically in the short-term but are, nevertheless, seeking ways to reduce their unit cost of production. Increasingly, they are prepared to adopt more rational approaches for nutrient and pesticide use, and to exploit alternative measures that minimise risks of problems arising that would otherwise require treatment with chemicals.

There are many ways to reduce production costs, either selectively or holistically, as part of strategies to improve farm income. Selectively-focused component research in a number of areas has contributed to these by providing options for reductions in agrochemical use that minimise environmental contamination. These include integrated nutrient management, forecasting systems for pests and diseases, reliant upon a basic understanding of population dynamics and other risk factors; reduced doses of herbicides, based on knowledge of the effects and interactions of weed growth, weather and soil conditions on herbicide performance; and improved spray technology. New developments in mechanical weed control, either alone or in combination with low doses of herbicides (Caseley *et al.*, 1993) may not only complement current weed control strategies, but also offer crop nutritional benefits from the nitrogen mineralised by mechanical intervention (Smith *et al.*, 1994). Recent research, that encourages natural enemies of pests and antagonists of diseases, or substitutes the use of biological control agents or behaviour-controlling chemicals for persistent pesticides, should also offer future opportunities to reduce the agrochemical load on the environment.

Other options in the development of reduced input systems involve manipulation and integration of husbandry practices within crop management.

Crop rotation is a key component in reduced and integrated systems of production, with maximum use made of crops that contribute positively to soil fertility. Crop rotation also provides options for reduced use of fungicides by decreasing disease carry-over from crop to crop, and herbicide reductions by permitting selective control of troublesome grass weeds in broad-leaved crops in the rotation without use of persistent herbicides. However, these effects and their interactions need to be examined over full rotational sequences in order to exploit the cumulative benefits.

Whilst selective reductions in nutrients and agrochemicals will reduce input costs, profitability can only be maintained by full and optimal integration of these exogenous variables within the whole system of crop management to ensure reliable yield at reasonable cost with an acceptable margin of profit. The long-term, farm-scale Less-Intensive Farming and Environment (LIFE) research project at IACR-Long Ashton, investigates opportunities to combine and optimally exploit all the above techniques and methodologies within an integrated farming systems approach. Research since 1989 (Jordan & Hutcheon, 1993; 1994) indicates that a less-intensive and integrated approach for arable crop production can maintain profitability by reducing the unit cost of production. There are also consistent indications of improved soil structure and quality, reduced agrochemical contamination and increases in soil flora and fauna, especially predators of key pests.

Based on the data generated from the LIFE project, prototype cropping systems, designed to be more environmentally benign than those currently in operation, have been formulated and implemented on two commercial farms in south-west England since 1992 in order to explore the feasibility and constraints of adopting such systems of production. This EU-funded Demonstration Project aims to demonstrate, to members of the farming industry, alternative methods and approaches that encourage farming practices which are compatible with environmental and natural resource protection; to provide on-site training in the principles and practices available for implementation; to appraise attitudes of members of the farming industry towards adoption; and to show that such systems are technically and economically viable.

MATERIALS AND METHODS

The LIFE Project

Established in 1989, this long-term, farm-scale experiment occupies a total of 23 ha. It comprises 20 field units (each of about 1 ha) within five fields, in order to compare four systems of production in fully-phased 5-course rotations. The four comparisons comprise a conventional rotation (CON) and an integrated rotation (IFS) each managed by standard farm practice (SFP), defined as that adopted by a technically competent farm manager and annually adjusted to reflect changes in conventional practice, and research-based lower input options (LI) (Jordan & Hutcheon, 1993). The crop rotations, husbandry practices and management decisions for the four systems of production have been well documented (Jordan & Hutcheon, 1994). Standard farm machinery is used throughout and a detailed diary of full husbandry records maintained. Comparative energy costs for machinery operations on the four production systems have been produced (Donaldson *et al.*, 1994). Crop yields are determined by taking 16 measured combine-cuts from pre-determined reference areas across each field unit and quality parameters are measured. Production costs (variable costs) are calculated on the basis of IACR-Long Ashton Farm purchase costs for seed, basal fertiliser, nitrogen and other nutrients, fungicides, insecticides, molluscicides, plant growth regulators and desiccants. The values for grain output are based upon HGCA average market price for the UK during the first week of October each year, for October delivery.

Commercial "Pilot" Demonstration Farms

Trerule Demonstration Farm and Bake Farm at Trerulefoot, Cornwall are sited in a central part of a 600 ha arable enterprise at Trerulefoot, Cornwall. The farms are in an area of great landscape value, on free-draining silty loam soil, with heavy winter rain contributing greatly to the annual rainfall of 1060 - 1270mm. Underground springs, most of which are piped to the nearest open water-course, and pockets of clay create a management challenge on the farm. On the commercially farmed land, key crops are winter wheat for animal feed, winter barley for malting and winter oats for milling. Other crops (oilseed rape, linseed, peas, beans) provide a natural break for these cereals; 60 ha of woodland fall within the farms' boundaries. In addition to the 40 ha permanent pasture (for 300 ewes), there is 4 ha of rough ground on which 10 different habitats have been established - four ponds, wetland areas, hazel coppice, meadow, fir plantation and new woodland planting. Wildlife is promoted within the boundaries of Trerule and Bake Farms, and 150 wild flower species have been identified.

The Trerule Farm unit (32 ha) was therefore selected because it has a favourable farm infrastructure for exploitation of the principles of integrated production. It comprises six fields (average field size 5 ha), with established field boundaries of traditional raised banks accounting for 3% of the land area. Thus, the following 6-course rotation was adopted for the integrated farming systems approach: winter wheat - winter oats - winter barley - setaside (natural regeneration) - "option crop" - spring crop (oilseed rape/linseed/peas) following a winter green cover.

Harnhill Manor Farm, near Cirencester, Gloucestershire, has been farmed by the Royal Agricultural College since 1987. The farm is situated on the edge of the Cotswold Limestone as it gives way to the alluvial soils of the Thames Valley and has a cropping area of 243 ha. Crops grown on the farm are mainly cereals (winter wheat, winter barley and spring wheat) and other combinable crops grown in rotation (winter beans, oilseed rape and linseed). Soil types are mainly Corn Brash and Forest Marble, with some overlying areas of clay loam and deeper alluvial soils. The farm is sited in a predominantly cereal growing arable area of the Cotswolds and is typical of the region. There are well structured hedgerows within and surrounding the farm, as well as managed woodland areas.

In contrast to Trerule Farm and the surrounding areas in Cornwall, many farms in the Cotswolds comprise large fields which are usually ploughed. As a consequence, soil erosion has been a problem in some years. In addition, one of the guidelines for Integrated Production states that *"the lateral dimension of an individual field should not exceed 100 m, otherwise fields need to be divided by annual or permanent vegetation to provide adequate ecological reservoirs"* (El Titi *et al.*, 1993). Therefore, the approach adopted at Manor farm was to convert a large field (Driffield Bank - 30ha) typical of the area, into an integrated farming systems unit, by dividing the field into six manageable units. Headland and boundary strips ("raised-banks"- 4m wide) were established between each field unit in spring 1993, and sown with various grass and wild flower mixtures. A 14m strip was also prepared centrally in the 30 ha field for establishment of a tree line. The following 6-course rotation was adopted in Driffield Bank: winter wheat - winter barley - winter beans - winter wheat - setaside (natural regeneration)- winter oilseed rape.

With the exception of winter beans which, at Harnhill, are broadcast and ploughed in as the method of establishment, all other crops are established using minimum/non-inversion tillage, and managed according to the guidelines for integrated production. All farming operations and the economic evaluation (crop yields, production costs, gross/net margins) for both commercial demonstration farms are done by the farm managers.

RESULTS

The LIFE Project

At harvest 1994, the LIFE project had completed its first 5-year cycle, so that all crops in the rotation have been grown on each designated field unit. Set-aside was introduced in autumn 1992, converting the conventional rotation from a 4- to a 5-year rotation and substituting set-aside for winter beans in the integrated rotation. Over the 5-year period, the lower input options on the conventional rotation reduced yields of "first-wheats" by 8%, "second-wheats" (grown only in 1990-1992) by 10%, barley by 11% and oilseed rape by 1%. However, these lower input options resulted in savings in production costs of 40% for "first wheats", 32% for "second wheats", 26% for barley and 29% for oilseed rape. With the lower input options in the integrated rotation, wheat yields (all "first-wheats") were reduced by 18%, due mainly to the selection of inherently lower yielding, disease resistant, quality cultivars; oat yields were reduced by 11%, and oilseed rape yields by 18%, whereas the yield of beans was increased by 5% (Jordan & Hutcheon, 1994). Thus, in the systems comparison, although this resulted in an overall 10 and 15% yield reduction in the conventional and integrated rotation, savings in production costs were 33% and 35%, respectively. In terms of profitability over the 5-year period, standard farm practice on both rotations gave gross margins of £577 ha $^{-1}$, whereas the lower input options on the conventional rotation increased gross margin by £37 ha $^{-1}$; however, in the integrated rotation gross margin was reduced by £18 ha $^{-1}$ (Table 1).

TABLE 1. Grain yields (t ha^{-1}), production costs and gross margins (£ ha^{-1}) from the LIFE project (1990-1994); 5-year means of the systems comparisons.

Crop	Yield (t ha^{-1})	Variable Costs (£ ha^{-1})	Gross Margin (£ ha^{-1})
Conventional rotation			
Standard Farm Practice	6.40	251.90	577.76
Lower Input Options	5.76	169.90	614.80
Integrated rotation			
Standard Farm Practice	5.92	230.28	576.60
Lower Input Options	5.05	148.96	558.45

Commercial "Pilot" Demonstration Farms

Trerule Farm, Cornwall:

In the 1993 harvest year, all crop yields, including those of crops grown conventionally on adjacent land (Bake Farm), were lower than the annual regional average for the previous 10 years (Table 2), due to climatically limiting variables. Nevertheless, responses and profitability from the "Pilot Farm" in this first transitional year, were most encouraging. By comparison with the 10-year conventional farm averages for the crops grown (GM = £621 ha $^{-1}$), the crops in the "Pilot Farm" grown under the guidelines for integrated production gave a farm average gross margin of £617 ha^{-1}, (Table 3).

TABLE 2. Economic Appraisal of Conventional Farm Practice at Trerulefoot (Previous 10-year Average) (GM = gross margin)

Crop	Production Costs (£ ha^{-1})							Yield	GM
	Seed	Fert	Herb	Fung	Pest	Othr	Total	tha^{-1}	£ha^{-1}
W.Wheat	47.1	89.0	41.6	43.5	0.0	4.7	226	7.5	674
W.Barley	44.9	65.8	39.0	43.6	1.6	29.8	225	6.9	672
W.Oats	39.5	68.2	20.2	48.2	1.6	23.2	201	6.8	615
Linseed	39.5	38.2	58.6	0.0	0.0	0.0	136	1.5	567
Sp OSR	22.6	35.5	0.0	0.0	3.6	0.0	62	2.2	576

TABLE 3. Economic Appraisal of crops grown under IFS guidelines at Trerulefoot -

1993 harvest year

Crop	Production Costs (£ ha^{-1})							Yield	GM**
	Seed	Fert	Herb	Fung	Pest	Othr	Total	tha^{-1}	£ha^{-1}
W.Wheat	52.7	49.2	33.3	21.4	6.0	0.0	164	5.2	497
W.Barley	57.6	49.7	57.3	17.9	0.0	0.0	183	5.6	619
W.Oats	49.1	49.7	45.4	21.4	0.0	0.0	166	5.0	569
Linseed	42.6	43.4	4.1	23.4	0.0	0.0	113	5.8	805
Sp OSR	53.6	32.3	10.2	0.0	0.0	0.0	96	1.7	595

1994 harvest year

Crop	Production Costs (£ ha^{-1})							Yield	GM**
	Seed	Fert	Herb	Fung	Pest	Othr	Total	tha^{-1}	£ha^{-1}
W.Wheat	27.9	50.6	46.7	29.6	6.0	0.0	161	5.5	614
W.Barley	37.8	28.3	35.5	31.0	0.0	11.8	144	5.5	795
W.Oats	40.0	43.3	35.5	31.0	0.0	11.8	161	4.8	688
Linseed	46.7	33.0	9.9	10.1	0.0	0.0	100	5.2	638
Sp OSR	45.4	7.6	46.6	0.0	2.1	26.6	130	1.9	610

** Gross Margin includes area payment.

TABLE 4. Economic data from conventionally grown crops at Bake Farm, Trerulefoot - 1994 harvest year

Crop	Production Costs (£ ha^{-1})	Yield (£ ha^{-1})	GM** (£ ha^{-1})
W.Wheat	175	6.6	672
W.Barley	189	5.4	699
W.Oats	134	5.9	652
Sp.OSR	125	2.6	691

** Gross Margin includes area payment.

In the 1994 harvest year, wheat yield was lower (< 1 t ha^{-1}) than conventionally grown wheat at Baker Farm, which resulted in a lower gross margin (Tables 3,4). This was attributed to the difference in the amount of applied nitrogen (99kg N ha^{-1} for IFS compared with 200kg N ha^{-1} for conventional). Therefore on this soil type, the decision-making process for N requirement, based on residual soil N, needs to be improved. Barley yields were similar to those conventionally grown and satisfied quality malting requirements (1.6% grain N). This resulted in a higher gross margin due to the reductions achieved in variable costs. The winter oats established well and were very competitive, therefore, no post-emergence herbicide was applied. In order to meet yield expectations and reduce the risk of crop lodging, only 50kg N ha^{-1} was applied (compared with 120kg N ha^{-1}on conventional oats). Whilst integrated oat yield was reduced and the growing costs lowered, a small(2%) loss in gross margin occurred. The spring oilseed rape, established after an overwinter green cover (forage rape), provided a reservoir for slugs and some damage occurred. Although a reasonable yield was achieved, the gross margin was eroded due to extra variable costs required in the establishment and treatment of the winter cover, prior to sowing the spring oilseed rape.

Driffield Bank, Harnhill:

Due to the late start for this farm conversion, spring-sown crops of wheat, barley, oats and beans were established in February 1993, to provide the correct crop entries for a winter-crop dominated integrated rotation to be sown in autumn 1993. Crops in the 6-course rotation at Harnhill for the 1993 cropping season were therefore: winter oilseed rape (established previously in autumn 1992) - spring wheat - spring barley - spring beans - spring wheat - spring oats (instead of "setaside" as derogation was not obtained in this preliminary year). All spring crops, except beans, were established using non-inversion tillage techniques and all crops were grown according to the guidelines for integrated production.

Whilst direct economic comparisons cannot be made between the spring-sown integrated crops (Table 6) and the previous year's averages for winter-crop dominated rotations (Table 5), the economic appraisal does provide an indication of the financial implications of such a transitional phase conversion. In addition, it does indicate the options for a spring-dominated cropping system managed under the guidelines for integrated production. However, caution should be taken in interpretation of these financial data, as the demonstration farm did not receive derogation for setaside due to the late start of the project. Therefore, two gross margin figures are provided, with gross margin adjustments for area payments given in parenthesis.

In the 1994 harvest year, both winter wheat crops were drilled under two different cultivation systems (Dutzi one-pass system or tined cultivation/ Accord drill) in order to compare crop establishment and yield. Initially, plant establishment was 48% lower with the Dutzi system than with the tined/Accord drill combination, but final yield was 16% higher in the areas sown using the Dutzi. In addition, whilst disease was notably less following establishment with the Dutzi system, weed infestations appeared greater, attributed partly to the weed

TABLE 5. Economic Appraisal of Conventional Farm Practice at Harnhill Manor Farm (Previous year's (1992) average)

Crop	Production Costs (£ ha^{-1})						Yield	GM*
	Seed	Fert	Herb	Fung	Pest	Othr	Total	tha^{-1}	£ha^{-1}
W.Wheat	47.7	74.8	42.8	31.0	2.2	4.1	202	6.0	485
W.Barley	31.5	67.4	67.0	40.8	0.0	2.2	209	6.0	456
WOSRape	24.5	80.0	50.0	21.1	13.9	0.5	190	3.0	568
Linseed	57.2	34.1	30.8	0.0	10.5	17.4	150	0.8	406
W.Beans	58.4	0.0	7.4	0.0	24.7	0.0	90	3.4	526

* Gross margins based on Sept 30, 1992 values for grain in store plus area payments owing of £400 and £500 for oilseed rape and linseed respectively.

TABLE 6. Economic Appraisal of crops grown under IFS guidelines at Driffield Bank, Harnhill

1993 harvest year

Crop	Production Costs (£ ha^{-1})							Yield	GM
	Seed	Fert	Herb	Fung	Pest	Othr	Tot	tha^{-1}	£ha^{-1}
Sp.Wheat	84.8	37.6	36.0	18.5	0.0	0.0	177	4.6	265 (405)
Sp.Barley	56.9	36.4	53.1	18.3	0.0	0.0	165	4.5	390 (695)
WOSRape	27.4	59.8	36.3	0.0	20.2	0.0	144	1.8	117 (561)
Sp.Beans	117.9	18.6	4.2	27.8	0.0	0.0	167	4.0	232 (598)
Sp.Oats	68.6	34.1	17.9	9.5	0.0	0.0	130	4.7	447 (587)

(Figures in brackets include area payment)

1994 harvest year

Crop	Production Costs (£ ha^{-1})							Yield	GM**
	Seed	Fert	Herb	Fung	Pest	Othr	Total	tha^{-1}	£ha^{-1}
W.Wheat	84.8	47.1	47.5	10.0	0.0	0.0	188	6.5	639
	69.3	41.0	55.0	10.0	0.0	0.0	175	5.4	544
W.Barley	49.1	43.0	23.1	24.0	0.0	0.0	139	4.9	632
WOSRape	24.4	47.8	39.3	0.0	10.0	0.0	120	1.2	474
W.Beans	57.9	0.0	9.2	19.8	0.0	0.0	85	2.9	549

** Gross margins include area payment

transplanting ability of the Dutzi in areas where glyphosate was not used. The integrated barley crop was sown in mid-October, and considered too late by local farmers to achieve acceptable yield. However, despite the relatively low yield (4.9 t ha^{-1}), malting quality was achieved. The winter beans, grown at a cost of £85 ha^{-1} (seed, weed harrow, low dose herbicide and fungicide), produced 2.9 t ha^{-1} with a very acceptable gross margin (Table 6). Winter oilseed rape, established using the Dutzi in late August, was slow to emerge. The crop reached cotyledon stage in September and hardly grew throughout the winter. Several factors may have contributed to this, such as poor seed/soil contact, cold temperatures, oat straw toxins and volunteers. Plant populations averaged 54 plants m^{-2}; the crop was attacked by pollen beetle at flowering and heavy rain occurred during pod-set. Thus, a low yield (1.2 t ha$^{-1)}$ and gross margin were obtained (Table 6).

DISCUSSION

Data generated from research into less-intensive farming for environmental protection (the LIFE Project) over the past 5 years has shown, through an integrated farming systems approach, a positive trend in economics, agrochemical and pesticide reduction and enhancement of beneficial organisms and processes, and identified farming practices that can be selectively modified to provide quality production without economic loss.

With regard to the husbandry practices and decision-making processes adopted on the demonstration farms, the pest, disease and weed strategies gave adequate and satisfactory control, but the decision models for applied nitrogen were considered to be less reliable, especially for quality wheat production. These are being re-appraised and refined within the LIFE project, and appropriate modifications will be included in 1994/95.

There has been a mixed response to IFS practices and procedures from members of the farming industry. Those on marginal land and/or those with mixed farms favour integrated production. Others, on the more productive arable land, tend to have higher overheads and therefore consider that they need high yields on all crops each year. In addition, there is still much dependence on high yielding cash crops (wheat and barley), because growing lower-yielding combinable break crops (oats, beans, peas and oilseed rape) can decrease the rotational farming system gross margin, irrespective of environmental benefits. Although some farmers have already adopted a more integrated rotation and have moved partially towards an integrated approach, farm economics are still the most important factor, thus motivation for change remains dependent upon economic advantage.

The response generated from the Demonstration Farms and at other associated events has convinced many farmers, especially in marginal areas, that adoption of IFS farming methodologies is feasible and a practical proposition. This has led to "satellite groups" of farmers willing to implement IFS principles alongside conventionally grown crops in order to, collectively, achieve hands-on experience and understanding of less-intensive systems of production. Furthermore, the introduction of the Directive on Nitrate Vulnerable Zones (NVZ) has stimulated some farmers to adopt integrated methodologies as a way of complying with this regulation. Farmers with soil erosion problems are also undertaking practices demonstrated on the Pilot Farms, in order to reduce land loss and overland drainage problems. This, in turn, is a major cause of environmental concern because of of silting-up of river courses. Environmental legislation coupled with environmental incentives seem to be the factors likely to encourage farmers to adopt integrated farming systems approaches.

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INTEGRATED FARMING SYSTEMS AND SUSTAINABLE AGRICULTURE IN FRANCE

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ABSTRACT

The concept of sustainable agriculture includes sociological, economical and agronomical aspects. In order to determine what the implications are for France, four trials on sustainable management for arable farms have been set up by ITCF and ACTA* in very contrasting regions. Conventional arable farming systems (CSF) are compared with integrated farming systems (IFS). CFS is the cropping system used by farmers in 1990 in the area where the experiments are situated. IFS represents a low input system and tries to minimise the environmental impact of the system. Trials are large-scale (15-75 ha) with large plots (2 to 5 ha) in order to measure the feasibility of the system and the economic and environmental parameters. After four years of the experiment, a significant reduction in the use of inputs and consequently input cost (25 to 37 %) was obtained especially for fertilisers, fungicides and insecticides. IFS strategies resulted in yield decrease (up to 32 % according to the crop) but the economic results were slightly better (with 1995 price conditions). However, many questions still need to be answered : intercrop management, minimum tillage techniques (ability to improve), weed control in an IFS context. It will be necessary to carry on the experiments for several more years in order to stabilise the system and verify the viability of the decisions making processes.

(*) **ACTA** : Association de Coordination Technique Agricole

INTRODUCTION

The concept of sustainable development was defined in 1987 by the Brundtland Commission in preparation for the Earth Summit which took place in June 1992 in Rio de Janeiro. The problem for the researcher is to put this concept into practice. For agriculture, we can say that the role of the farmers is to feed humanity, to preserve a safe environment (for the long term) and to use natural resources carefully. Then, there are three roles for sustainable agriculture : economical, ecological and social. Can agronomists be more positive and describe accurately cropping systems which are sustainable ? For the last ten years, many researchers have proposed the integrated farming system (IFS) as an answer to this question. A review of integrated farming experiments was produced by Holland *and al.* (1994).

Some results are available in this paper, but they are generally preliminary results. The long term implications of IFS or low input strategies on agronomy or environment are not known.

In this paper, the results obtained from three French sites after one complete rotation (3 or 4 years according to the experimental site), are presented.

MATERIALS AND METHODS

A four trial network was laid out in France during the cropping season 1990-1991. Three of these trials were set up by ITCF, the last one, not presented here, was set up by ACTA. During the first two years, this project was linked with an European network financed by the E.U. Research Program CAMAR.The project aims to provide economic and technical references for integrated arable farming systems (IFS).

The three trial locations were chosen according to their soil and climate characteristics (table 1).

The size of the experimental plots ranges from 2 to 5 ha. Every crop is present each year but there is no replication. At each experimental site, for each crop and for each devised system, the crop husbandry techniques were described before starting the experiment.

TABLE 1- Site details

	Boigneville	Saint-Hilaire	Montgaillard
Soil type	Loam	Loamy clay	Calcar. Clay hilly
Climate	Oceanic dry	Continental	Contrast
Annual rainfall	663 mm y^{-1}	794 mm y^{-1}	655 mm y^{-1}
Rotations	• Half deep soil : - peas - durum wheat - winter wheat • Shallow stony soil : - oilseed rape - winter wheat - spring barley	- oilseed rape - winter wheat - spring barley	- sunflower - durum wheat - winter peas - durum wheat
Systems in comparison		Conventional Integrated	

At each site, two main management systems are compared. A conventional farming system (CFS) where the most common practices of the local farmers are carried out. These crop management are not stable during the four years and are adapted each year to the farmers practices. For example, in Montgaillard, the variable costs in 1991 were 2669 FF./ha and have decreased to 1940 FF./ha in 1994.

The IFS is, as far as possible, close to the principles and technical guidelines defined by the IOBC/WPRS working group (El Titi *and al*., 1993). The main aspects are, rotation as long as possible according to the soil and climate condition, minimum three course, shallow cultivation and a lower target yield, about 20 % less than the soil-climate potential. For winter wheat, cultivars resistant to diseases, are chosen, sown at a low density and a sowing date delayed by about one week. In regard to crop protection, all crops are managed in order to minimise disease development : less nitrogen, lower sowing density, etc... In addition, chemicals were only used when thresholds were reached. No growth regulators were used. During the intercrop period, mechanical weed control has been used to control weeds. On the crops, early treatment combined with low doses of herbicides was used.

Numerous observations are made : The crop establishment is subject to particular monitoring that is essential since the soil cultivation is different between CFS and IFS (deep cultivation with a plough in CFS and soil cultivation at 7-10 cm deep in the case of IFS). Emergence losses as well as the crop growth rates during early growth stages are recorded. Pests are especially observed during early growth stages : sitona (*Sitona lineatus*) and thrips (*Thrips angusticeps*) on winter or spring peas, wireworms (*Agriotes spp*) on sunflower (*Aphis fabae*) are especially observed and treated if necessary... The weed flora development is subject to accurate surveys and weeds are mapped in the plots. Diseases are monitored with direct observations on plants but also with the use of prediction models especially on winter wheat. Yields are measured on harvest areas that have been defined after a methodological study. Quality of the harvested products is obtained through sample analysis. The type of analysis is adjusted to suited each product. Economic aspects : all data necessary to do comprehensive calculations have been recorded, machinery costs included purchase costs, repair costs, fuel and lubricant consumption for each field operation according to soil conditions, in order to take into account the labour time.

For each purchased input (seeds, fertilisers, pesticides...) date of purchase and amounts applied have been registered. All these costs are processed to give a set of economic indicators such as gross margin, direct margin, net margin for each crop and each rotation. Additionally, with the help of an interactive computer program devised by ITCF (SIMU-GC), overall results for the farm : net income, balance sheet and cash etc, can be obtained. In addition, technical indicators such as working times, equipment wear and tear rate are analysed.

RESULTS

The results are a precise description of each system and of the decision making process for each crop in each site. This aspect is very important when cropping systems are studied because the main objective of the research is not really to compare the two systems but to improve each one. For that purpose, each year the gap between forecast and real results is analysed (Viaux, 1994). Another reason for this methodology is to facilitate the transfer of technology of the new system to farmers.

Soil tillage and crop establishment

In IFS, all the crops were established with non inversion tillage. After harvest, the crop residues were chopped and immediately incorporated in the soil in order to facilitate the decomposition of crop residues and also to provoke a flush weeds and volunteers. This was followed by an other cultivation two months later. This strategy has some advantages after several years. The trafficability and natural drainage are better and there is no soil compaction. But for spring crops (peas or spring barley), after a very wet winter, the sowing date was delayed. Nevertheless in Montgaillard, there was less erosion with the sunflower crop in may 1992 in the IFS treatment due to crop residues on the soil surface.

The losses at emergence are higher with IFS when compared with CFS. These losses can reach 50 % for a spring crop due to the bad position of seeds or, in some years, to pest development : thrips angusticeps on peas and wireworms (*agriotes* spp) on sunflower. After four years of trials, it seems that shallow cultivation can slightly increase some soil pests but no specific slug problems were observed.

Weed control

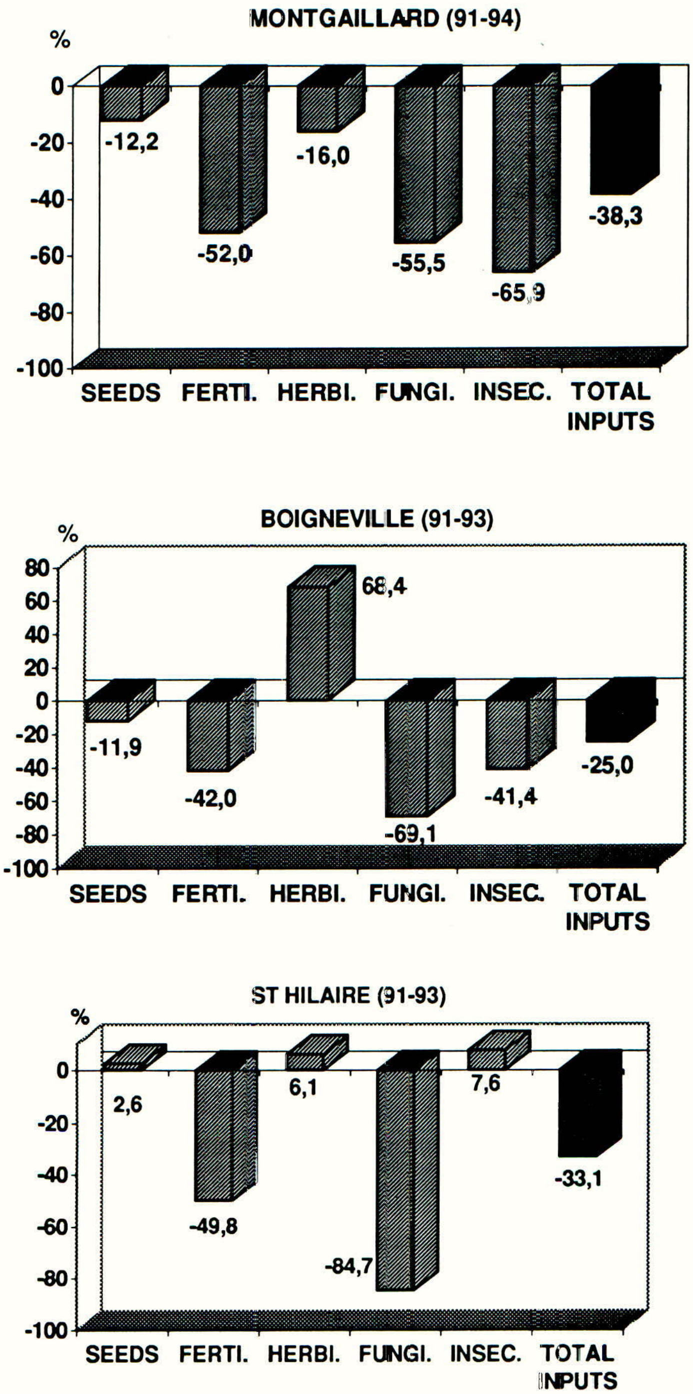
Weed control is probably the main problem to manage with IFS. This is partly due to the tillage technique. Herbicide costs can be reduced of 16 % at Montgaillard but in the two others sites they are higher in IFS. Since the first year of experiment, there have been some problems with annual weeds like cleavers (*Galium aparine*) in peas in Boigneville and Montgaillard and wild oat (*Avena fatua*) on wheat that could not be controlled correctly. After several years, the difficulties are increasing. Annual weeds like blackgrass (*Alopecurus*) are more significant in IFS compared with CFS in Saint-Hilaire. In Boigneville, there is a lot of Bromus (*Bromus sterilis*) on the edges of the plot. But the main problems are with perennial weeds : thistle (*Cirscium arverse*), couch grass (*Elymus repens*), convolvulus dock (*Rumex acetosella*), specifically in Montgaillard.

To improve the weed control, the intercrop period has been managed more carefully. Just after harvest, the soil is cultivated with a disc-harrow to incorporate crop residues and to favour weed and volunteer emergence. After about two months, a disc-harrow is used again in dry conditions to destroy these weeds and volunteers, 90 % of the emerged weeds can be destroyed by this method. For the spring crops and if the weather is dry, a third pass is done in November. Otherwise, glyphosate is used before drilling. At Boigneville this strategy used in 1994 allow a significant reduction of herbicide costs in IFS (539 FF./ha in 1992, 272 FF./ha in 1994).

Disease control

This is probably the most interesting result of this experiment. The holistic approach to disease control by combination of resistant cultivars, low nitrogen inputs, delayed sowing dates, etc...has allowed a strong reduction in fungicide inputs : 55 % in Montgaillard, 69 % in Boigneville, 87 % in Saint-Hilaire. Reductions are more important on cereals than on other crops. Generally speaking, the disease pressure is lower in Saint-Hilaire, that is why the highest reduction is observed on this site. Nevertheless, diseases are controlled in each case at the same level. Some diseases like eyespot are tolerated under 25 % of plants infected at stem elongation stage, some others are totally controlled like brown rust in the South West.

Figure 1 : Average percentage of reduction of variable costs with IFS compared to CFS (1991-1993 or 1991-1994)



Fertilisation

The fertilisation is also largely reduced (by 42 to 52 % according to the site). All macro elements are included in this reduction : N, P, K. For example, in Montgaillard, the average N input in the rotation is 95 kg/ha in CFS and 48 Kg/ha in IFS, with a maximum of 222 kg/ha on durum wheat on CFS in 1994 versus 175 kg/ha the same year in IFS. On the same site 83 kg ha^{-1} yr^{-1} P_2O_5 is applied to CFS and 50 kg ha^{-1} yr^{-1} to IFS.

Nitrogen is generally reduced by about 20 to 30 % on cereal crops. The reduction could be higher on oil crops (no nitrogen on sunflower with IFS).

Total inputs

IFS can save a lot of inputs (Figure 1) when compared with CFS. On average for rotation, this reduction can reached 26 to 38 % according to the site. The target at the beginning of the experiment was 35 %. As seen above, the reduction in inputs is variable according to each input. The reductions are significant for fertilisation and fungicide, and very low for herbicides and seeds. The insecticide case is misleading because the reduction can be quite high (66 % at Montgaillard) but the input level to CFS is low in absolute terms (132 FF./ha).

YIELD AND ECONOMIC RESULTS

Whatever the crop and the site, the yields were lower in IFS when compared with CFS. For winter wheat, the gap ranged from 0.9 t ha^{-1} at Montgaillard to 2 t ha^{-1} at Boigneville and Saint-Hilaire. At Boigneville, the gap was higher than on the other sites, especially on spring crops, because of the poor plant establishment for the two first years.

In general terms, at all sites there has been an improvement in concerning the management of IFS and, in the last few years the gap between CFS and IFS is decreasing. For example, with yields of winter wheat at Boigneville the gap between IFS and CFS decreased from 34 % to 14.8 % (Table 2), when averaged over two rotations.

Table 2 : Yield of winter wheat at Boigneville. Average of two rotations (t ha^{-1})

	1991	1992	1993	1994
CFS	8.95	5.60	8.80	7.75
IFS	5.85	4.50	7.40	6.60
Δ (%)	- 34.6	- 19.6	- 15.9	- 14.8

These gaps in yields are nevertheless quite different from those observed in other European countries. The differences between IFS and CFS are generally lower than in France (about 3 % at Lautenbach in Germany, about 10 to 15 % at Long Ashton in U.K.). These differences are due to the absolute level of CFS. CFS is not really a high input system because the French farmers have already reduced their input in the regions where the trials have been set up for the last 10 years. The second reason is that nitrogen and fungicides which are the main factors for yields have been strongly reduced in the French IFS.

Despite this yield reduction, the economic results (Table 3) are really interesting. When 1995 prices are used, the gross margin are better at Montgaillard and at Saint-Hilaire for IFS than for CFS.

The net margins are better with IFS in every case. This is due to the mechanisation costs which are lower with IFS because of lower soil tillage costs. These net margins do not include labour costs. The time spent on IFS in the field is lower than in CFS : at Montgaillard, CFS needs 6 h ha^{-1} yr^{-1} of labour while IFS needs only 4.8 h ha^{-1} yr^{-1}. At Boigneville, CFS needs 8.1 h ha^{-1} yr^{-1} and IFS 4.8 h ha^{-1} yr^{-1}. These differences would theoretically increase the economical advantages of the IFS. Nevertheless, the time spent to observe the crops has not been measured and IFS needs more time for applying decision making processes.

Table 3 : Yields and economics results

Montgaillard (31)

Average 1991-1994

	CFS	IFS
Yield (Ton/ha)		
Durum Wheat	6,6	5,5
Winter Wheat	7	6,1
Winter Peas	4,4	4
Sunflower	2,4	2,4
Inputs (FF/ha)	**2185**	**1348**
Gross Margin (FF/ha)	**4568**	**4870**
Net Margin (FF/ha)	**1355**	**1848**

Boigneville (91)

Average 1991-1993

	CFS	IFS
Yield (Ton/ha)		
Durum Wheat	5,5	4,7
Winter Wheat	8,3	6,2
Spring Peas	5,7	3,5
Oil Seed Rape	2,3	1,5
Spring Barley	6,3	4,8
Inputs (FF/ha)	**2118**	**1506**
Gross Margin (FF/ha)	**5205**	**3814**
Net Margin (FF/ha)	**815**	**942**

St Hilaire (55)

Average 1991-1993

	CFS	IFS
Yield Ton/ha		
Winter Wheat	7,7	5,7
Oil Seed Rape	3,2	2,6
Winter Barley	6,4	4,7*
Inputs (FF/ha)	**1979**	**1493**
Gross Margin (FF/ha)	**4679**	**4767**
Net Margin (FF/ha)	**512**	**736**

* Spring barley in IFS

DISCUSSION

After four experimental years, it is not possible to conclude to make definite conclusion from these results. Firstly, because the IFS system is not really stabilised, eg. for weeds. Every year, some new problems arise or increase : bromus in Boigneville, rumex, thistle and many perennial weeds in Montgaillard or blackgrass in Saint-Hilaire. On the other hand, some improvements are seen, for example, an increase of the topsoil organic matter and more earthworms in IFS. Further information is needed on the environmental impact of these systems. Ceramic cups have been set up in Boigneville to measure nitrate leaching but it is too early to analyse these results. Nevertheless the economic results could be extrapolated to farmers.

The main difficulty in transferring the IFS technology to farmers is the variability of the results. At first, it is likely that the farmers, who adopted these techniques, will observe some variability in performance at the beginning , but as we have shown in this paper, this is mainly due to a lack of knowledge. Some other ITCF results (not published) show that low input systems do not result in an increase in variability of cereals if they are correctly managed.

An other unknown point is the time necessary to observe the crops before making a technical decision. We cannot measure this time in our experiments but it is certain that IFS needs more time than the other system.

This experiment highlights that there is a lack of technical references for optimising the integrated farming systems. We can give an unlimited list, for example we need more disease resistant cultivars of wheat with good baking quality even with low nitrogen inputs. There is a lack of knowledge concerning how to manage herbicides when shallow cultivation is used. We need some more efficient methods to appreciate thresholds in real fields. It is unacceptable for a farmer to spend too much time counting aphids in a wheat field when the price of an insecticide treatment is very low.

After this first period in which a complete rotation has been studied, the experiment is caring on but with a lot of changes. The rotation for the reference system is being simplified to be closer to the farmers practices. Generally, a two year crop rotation will be used : wheat/peas in Boigneville, oilseed rape/wheat in Saint-Hilaire and sunflower/wheat in Montgaillard. For IFS, there is little evolution except on soil tillage in Montgaillard . Because of the difficulties in controlling weeds, we have decided to introduce the plough one year out of four (this is also the case on the LIFE project in UK). In the next four years, we aim to increase the measurement of the environmental impact of the two systems.

Lastly, we are starting a new experiment with ACTA to improve our knowledge about the intercrop management with shallow cultivation and with or without catch crops. This experiment is partly financed by EU in the AIR III program.

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