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WORKING GROUP "INTEGRATED ARABLE FARMING SYSTEMS"

GROUPE DE TRAVAIL "AGROSYSTEMES INTEGRES"

CURRENT STATUS OF INTEGRATED FARMING SYSTEMS RESEARCH IN WESTERN EUROPE

EDITED BY / EDITE PAR P. VEREIJKEN & D.J. ROYLE

WPRS BULLETIN
BULLETIN SROP

1989 / XII / 5

International Union of Biological Sciences

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL AND INTEGRATED CONTROL OF NOXIOUS ANIMALS AND PLANTS

WEST PALAEARCTIC REGIONAL SECTION

IOBC WPRS   OILB SROP

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ENGLISH PREFACE

This first bulletin since the IOBC/WPRS Integrated Arable Farming Systems Study Group changed to a Working Group, gives state-of-the-art reports from each of the 8 current member countries (see list of members, p.v). In the past 3 years of its existence the Working Group has come to a common understanding of the concepts of Integrated Farming Systems (IFS) (see p. vi).

We have defined the objectives of the Group as:

- development and evaluation of IFS appropriate to specific growing areas;
- mutual support in the planning and execution of farming systems experiments, through exchange of methods and results on design and management, analysis, development and evaluation and introduction in practice;
- encouragement of individuals and groups within and outside IOBC to contribute or participate for example through workshops, teach-ins and joint publications (especially IOBC-bulletins).

In order to encourage an actively functioning Group that adheres to its original objectives, we have tried to ensure that membership is limited to those who are actively involved in research of integrated arable farming systems, preferably in designing and coordinating roles. For our annual meetings we intend to invite a number of experts to help evaluate local experiments.

This bulletin shows that some countries already have extensive research programs in IFS with very promising results, whilst other countries still are at the planning stage or else about to start first experiments. We hope that these just starting will make quick progress in the next few years, and gain much benefit of those who have been involved in IFS for several years. Finally, we hope that other countries especially from the Mediterranian area, will join the Working Group during the next few years.

The editors:

P. Vereijken, convenor
D.J. Royle, IOBC council representative

June 1989

PREFACE FRANÇAISE

Ce premier bulletin, depuis que le groupe d'ëtude OILB/SROP sur les Agro-systèmes Intégrés est devenu un groupe de travail, fait le point sur l'état d'avancement des travaux dans les huit pays membres de ce groupe (voir p.v). Au cours de ces trois dernières années, le groupe est parvenu à une conception commune sur les concepts des systèmes intégrés en grandes cultures (IFS).

Nous avons défini les objectifs du groupe comme étant:

- développement et évaluation de IFS de manière adaptée aux différentes zones de production;
- une aide mutuelle quant à la programmation et la réalisation d'expérimentations sur les systèmes intégrés, par l'échange de méthodes et de résultats sur les objectifs, les techniques, les analyses, le développement et la mise en pratique;
- l'incitation, pour des individus ou des groupes appartenant ou non, à contribuer ou participer aux réunions de travail, cours et à des publications conjointes (particulièrement aux bulletins de l'OILB).

Afin d'encourager un groupe actif qui réponde à ces objectifs initiaux, nous nous sommes assurés que les membres se limitaient à ceux qui sont activement impliqués dans la recherche sur les systèmes de production intégree et de préférence ayant des rôles de coordination et de définition des expérimentations. Lors de nos réunions annuelles, nous avons l'intention d'inviter un nombre d'experts dans le but de réaliser des évaluations des expérimentations locales.

Ce bulletin est la preuve que certains pays sont déjà engagés dans des programmes de recherche sur IFS avec des résultats très prometteurs, alors que d'autres en sont à la programmation ou sur le point de démarrer les premières expérimentations. Nous espérons que celles-ci vont faire de rapides progrès dans les prochaines années et tirent un maximum de profit des experimentations en cours depuis plusieurs années déjà. Finalement, nous espérons que d'autres pays, et notamment du bassin méditerranéen, rejoindront ce groupe dans les années à venir.

Les redacteurs,

P. Vereijken, responsable du groupe
D.J. Royle, réprésentant du Conseil d'OILB

(Traduction: A. Fougeroux)

Juin 1989

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Objectives of integrated farming systems
(English, French and German versions)

Integrated farming is trying to serve both economic and ecological aims by:

1. Shifting the emphasis from greater production to cost reduction and improvement of quality of both products and production ways, through substitution of expensive and potentially harmful inputs, especially fertilizers and pesticides, by both agricultural and ecological knowledge, labour and non-chemical husbandry techniques.

2. Encouragement and conservation of flora and fauna in and around the fields, to stabilise the agro-ecosystem as a major preventive measure against the outbreak of pests, weeds and diseases.

As the main social effects of this integrated farming strategy it can be expected:

a. Less pressure on profits of the agricultural holdings at increasing cost of production means and decreasing prices of products.
b. Less pollution of the environment.
c. More safety for public health and nature/landscape.

Some forms of biological or organic farming may be considered as the most radical approach of these integrated objectives. On the long term it may also appear the most desirable approach, provided the necessary technical and economic improvements can be made.

Objectifs des agrosystèmes intégrés ou extensifs

Les agrosystèmes intégrés ont pour objectifs:

1. De déplacer l'intérêt mis sur l'accroissement de la production vers une réduction des coûts et une amélioration de la qualité, tant des produits agricoles que des modes de production, en substituant progressivement à des intrants coûteux et/ou dangereux (fertilisants, pesticides ...) des méthodes agronomiques et écologiques plus élaborées, des intrants biologiques et culturaux ainsi que la main d'oeuvre.

2. De favoriser et de maintenir de la diversité botanique et zoologique dans les parcelles et leurs alentours pour stabiliser les agroécosystèmes et de réduire les risques phytosanitaires.

Sur un plan général, les principales conséquences attendues de cette stratégie sont:
a. une moindre contrainte sur les revenus de l'exploitation, ceux-ci devenant moins sensibles à l'augmentation du coût des moyens de production.
b. une moindre pollution.
c. une réduction des risques pour la santé publique, la nature et le paysage.

Dans cet esprit, certaines formes d'agriculture biologique peuvent être considérées comme les approches les plus radicales des agrosystèmes intégrés.

Ziele des integrierten Landbaus

Der integrierte Landbau versucht, sowohl ökonomischen als auch ökologischen Zielen gerecht zu werden und zwar durch:

1. Die Verschiebung der Betonung von Produktionssteigerung zur Kostensenkung und Förderung der Qualität sowohl der Produkte als auch der Produktionsmittel.
   Dies soll erreicht werden durch den Einsatz teurer und potentiell umweltgefährdender Mittel, insbesondere von Mineraldünger und Pflanzenschutsmittel durch den verstärkten Einsatz von produktionstechnischem und ökologischem Wissen, durch Arbeitskraft und durch die konsequente Nutzung ackerbaulicher Maßnahmen zur Herabsetzung der Schadenswahrscheinlichkeit.

2. Förderung und Erhaltung von Flora und Fauna innerhalb der Felder und der sie umgebenden Bereiche, um das Agroökosystem, das als bedeutender Faktor zur Verhinderung des Massenauftretens von Schädlingen, Krankheiten und Unkräutern fungiert, zu stabilisieren.

Als wesentliche gesellschaftspolitische Auswirkung dieses integrierten Landbausystems kann erwartet werden:

a. Verringerung der Einkommensdruckes auf landwirtschaftliche Betriebe durch sinkende Kosten der Produktionsmittel bei steigenden Produktpreisen.

b. Geringere Umweltbelastung.

c. Geringere Gesundheitsrisiken für alle.

Die Formen des ökologischen Landbaus können als der radikalste Ansatz in dieser Richtung angesehen werden.

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RESEARCH REPORTS

INTEGRATED PILOT FARM IN ILZ,AUSTRIA

H.K.BERGER, Federal Institute for Plant Protection, Vienna

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H.PFINGSTNER , Federal Institute of Agricultural Economics, Vienna

Summary

In Ilz, Austria, a commercial farm of 150 ha is being converted to integrated plant production methods. This is occurring in gradual stages in cooperation of the owner and based on results of field experiments at the site. The project is guided and evaluated by the authors.

In experimental,integrated plots green manure crops have been grown after the main crops wheat and maize. In winter wheat a new variety has been introduced with high resistance against diseases. The input of the pesticides to wheat was reduced by 48 % in 1988.

Introduction

Towards the end of 1985 the owner of the "Feistritz"-farm in Ilz, Styria who had heard about the "Lautenbach-project" near Stuttgart (Steiner et al.,1986) asked us to start a similar project on his farm .He wanted to change gradually to integrated production methods , because of increasing problems with soil structure, weeds and costs of herbicides.

The farm occupies 150 ha, 148 ha of which is arable land. The soil type varies from pH 6.2 - 6.4 and a humus content 2.4 - 2.6 %. Annual average temperature is 8.5^{0}C, annual rainfall is 750 mm and the farm is 276 m above sea level. Figure 1 shows the layout and size of fields.

The crop rotation previously consisted of 1/3 winter wheat and 2/3 maize, as is usual in this part of Styria. For economic reasons for example investment in existing equipment, the farmer is not yet prepared to change this rotation . If economically valid alternatives become available however, he may expand his currently limited rotation.

Experimental design

Because of administrative and personal difficulties the project could not start in the spring of 1986, as was planned. In that year only 4 ha of a resistant variety of winter wheat were sown for experimental use. In autumn 1986 a rotavator ("Roto-Tiller") was tested on maize stubble . Due to an excessive amount of maize straw and wet weather, this trial had to be stopped.

In spring 1987, several soil parameters in areas to be allocated to integrated and conventional sytems were checked as base level references for the proposed 5 - 10 years of integrated farming. Populations of soil surface organisms, such as carabids, staphylinids and cicindelids were sampled with pitfall traps. In addition, the number of earthworms in 0,5 m^2 were determined. Soil analyses were done from three profiles within each field: precise amounts of humus content, P_2O_5, K_2O and total N were determined. The soil was examined in detail by soil specialists in order to be able to compare soil structure and nutrient content after fixed intervals (over 5-10 years).

For the project work fields of both winter wheat and maize were divided into conventional and integrated plots. In each plot 1 ha was delimited for, so to provide samples for the analyses.

Initial results

Trials in 1987

On both conventional and integrated plot of wheat , a new Austrian variety, Ikarus was sown. Because this variety is resistant to diseases no fungicides or growth regulators were used on the integrated plot. The conventional plot was treated by the farmer in his usual manner (Table 1). Ikarus was used on both plots to show the advantage of resistant varieties compared to non resistant ones.

Table 1: Chemical control of diseases on the conventional plot (1987).

Fungicide	Dosage (a.i./ha)	Disease
Prochloraz (Sportak 1.5 l/ha)	477 g	*Pseudocercosporella* *Erysiphe graminis*
Propiconazole (Tilt 2 x o,5 l/ha)	400 g	*Pseudocercosporella* *Erysiphe graminis*
Chlorthalonil (Bravo 500 1.5 l/ha)	1.500 g	*Septoria nodorum*
CCC (Stabilan 0.4+0.6 l/ha)	460 g	as growth regulator

Monitoring the crops (by the Cereal Department of the Federal Institute of Plant Protection) indicated a treatment against *Pseudocercosporella* would not have been necessary, in contrast to *Septoria* where treatment was required. Due to heavy and continous rainfall from end of July until 20 August there were serious outbreaks of *Septoria* .

The integrated plot yielded 820 kg/ha less than the conventional plot, probably because of the effect of *Septoria* Consequently the gross margin of the integrated plot was öS 199.-- lower than that of the conventional plot. Following harvest Phacelia was sown on both plots.

The maize variety Dea (Pioneer) was sown on both plots: after ploughing the conventional plot in autumn 1986, and after having grown oil radish in the integrated plot in the autumn 1986 and than ploughing.

Herbicides were applied overall in plots of both systems. There were no other chemical treatments. The infestation of the European Corn Borer (*Ostrinia nubilalis* Hbn.) was low and no control was necessary. The economic results , for both winter wheat and maize are shown in Table 2.

Earthworms were sampled in spring,1987 by using 0.2%

formaldehyde with 2 x 5 l water and again in autumn, 1987. In each of the two wheat and two maize plots, nine samples of o.5 m^2 were taken. Large numbers of surface arthropods were caught in pitfall traps. Five traps were set in each of the four plots. They were emptied and refilled every 10-12 days. The investigation began after maize has been sown (beginning of May) and ended at the end of September .

Table 2: Economic results of the conventional and integrated field in 1987 (öS/ha)

(a) Winter Wheat

	Conventional	Integrated	% of Convent.
Yield (kg/ha)	6,500	5,680	87
Total returns	22,750	19,880	87
Variable Costs	12,996	10,325	79
Gross margin/ha	9,754	9,555	98
Gross margin/man hours	629	735	117

(b) maize

	Conventional	Integrated	% of Convent.
Presowing Oil radish			
Yield/ha (kg/ha)	9,200	9,670	105
Total returns	30,636	32,201	105
Variable Costs	17,682	19,698	111
Gross margin/ha	12,954	12,503	97
Gross margin/man hours	810	658	81
Presowing Phacelia			
Yield kg/ha	9,200	9,940	108
Total returns	30,636	33,100	108
Variable Costs	17,682	20,330	115
Gross margin	12,954	12,770	99
Gross margin/man hour	810	672	83

The pitfall traps were 1/4-filled with diethylenglycol. Numbers of earthworms and arthropods are shown in Table 3.

Table 3: Ecological monitoring: epigaeic insects *) and earthworms (Lumbricidae) *) (1987)

a) Winter Wheat : (9 June - 24 July 1987)

	Integrated	Conventional
Carabidae	264	334
Araneae	43	129
Staphylinidae	19	51
Coleoptera larvae	8	25
Myriapodae	0	2
Lumbricidae	13	11

b) Maize (9 June - 2 September 1987)

	After Phacelia	After Oil Radish
Carabidae	813	426
Araneae	42	80
Elateridae	3	2
Staphylinidae	61	53
Myriapodae	83	47
Coleoptera larvae	32	12
Lumbricidae	161	160

*) The numbers represent the numbers of earthworms per m2 resp. the numbers of arthropods caught in pitfall traps.

Trials in 1988

Since the climatic conditions in spring, 1988 were unfavourable, certain maize projects (e.g. band spraying) could not be carried out as planned .
The winter wheat trials,however, were carried out according to plan. Two fields, each of about 25 ha were sown with the varieties Ikarus and Rektor in both conventional and integrated areas. In each field 1 ha was used for sampling .

The weather was favourable in autumn and the wheat overwintered well. Growing conditions in spring were also favourable for a high yield. Nitrogen applications (170 kg/ha) was split into three timings .Table 4 summaries the plant protection measures adopted.

Table 4: Chemical Control on the winter wheat fields in 1988

Treatments (per ha)	a.i.(g/ha) Conventional	Integrated
Herbicides		
Methabenzthiazuron (Tribunil 3 kg)	210	210
Bromoxynil (Oxydril 3,5 kg)	1.837	1.837
Growth regulator		
CCC (Stabilan 0.7+0.5 l)	449	449
Fungicides		
Carbendazim+Prochloraz (Sportac 1.5 l)	637	637
Anilazine (Dyrene 4.o+2.ol)	450	-
Triadimenol (Baytan0.5+0,25l)	165	-
Insecticides		
Deltamethrin (Decis 0.5 l)	125	-
Total a.i./ha	3.873	3.133

In the integrated plot only 80.9 % pesticides were used (conventional = 100 %).

Only low levels of mildew, *Septoria* and *Pseudo - cercosporella* were encountered in 1988.

The yields of the integrated plots were slightly less than the conventional plots (Table 5)

Table 5: Economic results of the conventional and integrated winter wheat fields in 1988 (öS/ha) (Size of the sample 1 ha)

a) Variety Ikarus

	Conventional	Integrated	% of convent.
Yield (kg/ha)	8.426	8.090	96
hl-weight	80.1	81.7	102
1000 grain weight	34.73	36.30	105
Total returns	30,165	28.881	96
Variable Costs	14,124	12,483	88
Gross margin/ha	16,041	16,389	102
Gross margin/ man hours	1,069	1,171	110

b) Variety "Rektor"

	Conventional	Integrated	% of convent.
Yield (kg/ha)	8,300	7,600	91
hl-weight	81.9	82.5	101
1000 grain weights	33.34	34.95	104
Total returns	29,797	27,208	91
Variable costs	14,110	12,429	88
Gross margin/ha	15,687	14,779	94
Gross margin/ man hours	1,046	1,056	101

Discussion

The trials and the adaption of the farm to integrated methods progressed slower than expected. The farmer needs to be convinced of the value of integrated agriculture "step by step" In his opinion, the minimum requirement is that farm income must be maintained so, only economic success motivates him to convert more fully to integrated methods.

Besides the farmer's own efforts and our trials' results, the Austrian government has established several other measures to encourage reductions in the proportion of maize in the rotation and to reduce the use of mineral and water soluble fertilizer in general. Thus the farmer has to pay extra tax for mineral fertilizer: nitrogen öS 5,oo /kg pure nutrient; phosphorus öS 3.oo /kg pure nutrient; potassium öS 1,50 /kg pure nutrient.And an extra tax for maize seed of öS 300,oo per package of 50.000 kernels.

In addition some alternative crops, e.g. oil seed rape, sunflower, soybeans, horse beans and field peas are supported by the government to help speed up the change in rotation from wheat and maize to integrated ("alternative") crops

All these measures should contribute to an increasing use of alternative crops followed by more integrated plant protection methods in the general agriculture in Austria.

References:

STEINER,H., EL TITI A., & BOSCH J. (1986) Integrierter Pflanzenschutz im Ackerbau: Das Lautenbach Projekt Zeitschrift für Pflanzenkrankheiten 93, 1-18

START OF FARMING SYSTEMS RESEARCH IN DENMARK

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INTRODUCTION

In Danish agriculturel research there is a general need for research in agro-ecosystems to elucidate the effects of plant production on the environment, including flora, fauna, physical and chemical soil parameters. In addition, the adverse effects of intensive plant production have recently received an increasing interest from the public and the politicians. In Denmark it has been decided that both nitrate leaching and pesticide consumption must be halved. Nitrate leaching is in focus because of its possible effect on ground and sea water, and pesticide consumption because of fear of residues in food, of health risks and of long-term effects of decomposition products in soil and ground water.

In regard to nitrate leaching in Denmark, particular attention is being paid to the handling, application and utilization of nitrogen in organic manure. This has been a driving force for farming systems research. Detailed experiments on organic manure and plant protection also can fit into the farming systems.

This was the background for long-term experiments with farming systems at three different research stations under the Danish Research Service for Plant and Soil Science (Mikkelsen, 1986a). These were established in 1986 at the locations shown in Fig. 1.

- Research Centre Foulum, 25 ha, coarse sandy loam
- Research Station Ødum, 16.5 ha, fine sandy loam
- Research Station Jyndevad, 18 ha, coarse sandy soil.

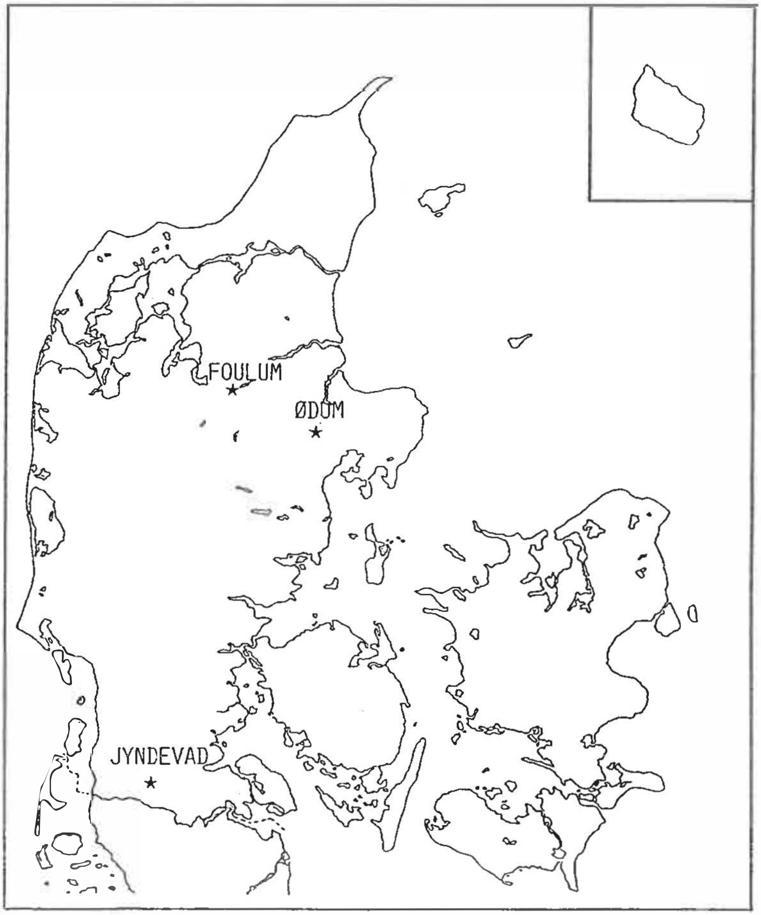

Figure 1: Map of Denmark with the locations of the three research areas.

ORGANIZATION OF THE RESEARCH PROJECTS

The farming systems experiments were started in spring at Foulum 1987, at Ødum 1988 and at Jyndevad 1989. Establishing the farming systems at state research stations gives optimum experimental facilities and possibilities, which may not be found at a private farm.

At the three locations the research projects comprise organic systems, integrated systems and a technological system (conventional system). The technological system was established at Foulum only, and consists of a single field for reference purposes.

A special inter-disciplinary project organization has been set up within the research service. It comprises a steering committee with financial responsibilities as well as research workers. The reason for this organization is the inherent holistic nature of the research, cf. the objectives listed below, and the fact that scientific expertise and resources from different departments of the research service are required.

The objectives of the Danish farming systems experiment (Mikkelsen, 1986b) are:

- to develop and improve cropping systems
- to acquire a greater knowledge of biological interactions and contribute to the development of economic and environmentally acceptable crop production.
- to consider the agricultural system as an ecosystem and to describe its characteristics.

Activities in the Danish experiment will include examining possible long-term trends (e.g. soil characteristics, plant yield and quality) and studying nutrient and energy balances within different farming systems

CHARACTERIZATION OF THE EXPERIMENTAL SITES

Prior to the start of the work, the experimental areas were carefully characterised with respect to chemical, physical and biological factors (Table 1). A special inter-disciplinary project organization was set up for this task. The methods used has been described in detail by Heidmann (1988), and results are to be published shortly (Heidmann, 1989). Measurements were made within a 40 x 40 m grid and yield determination and aerial photography of various cereal crops were performed.

The results from this soil survey gave an opportunity to study the spatial variation of various soil parameters. As an example, Fig. 2 shows the spatial variation in total carbon content at 0 to 20 cm depth at Jyndevad. This variation must be taken into consideration when interpreting future measurements in the different farming systems.

Table 1: Variables measured during the initial characterization of the experimental area.

LOCAL TOPOGRAPHY	
SOIL PROFILES	
SOIL PHYSICS:	texture, specific gravity, consistency, plant available water, bulk density, saturated hydraulic conductivity, air diffusivity, air permeability (massflow), water retention
SOIL CHEMISTRY:	R_t, P_t, K_t, exchangeable Na^+, K^+, Mg^{++}, Ca^{++}, Cu_t, P_{inorg} and P_{tot}
ORGANIC MATTER:	C_{tot}, N_{tot} and P_{org}
MICROBIOLOGY:	microbiological activity (CO_2-production), microbial biomass (ATP-index and Jenkinsons biomass-index), denitrifying bacteria (MPN) and mycorrhiza (VAM-infection af VAM-diaspor.)
FAUNA:	earthworms, collembola and soil-borne pests
YIELD MEASUREMENTS	
NEAR INFRARED AREAL PHOTOGRAPHY	

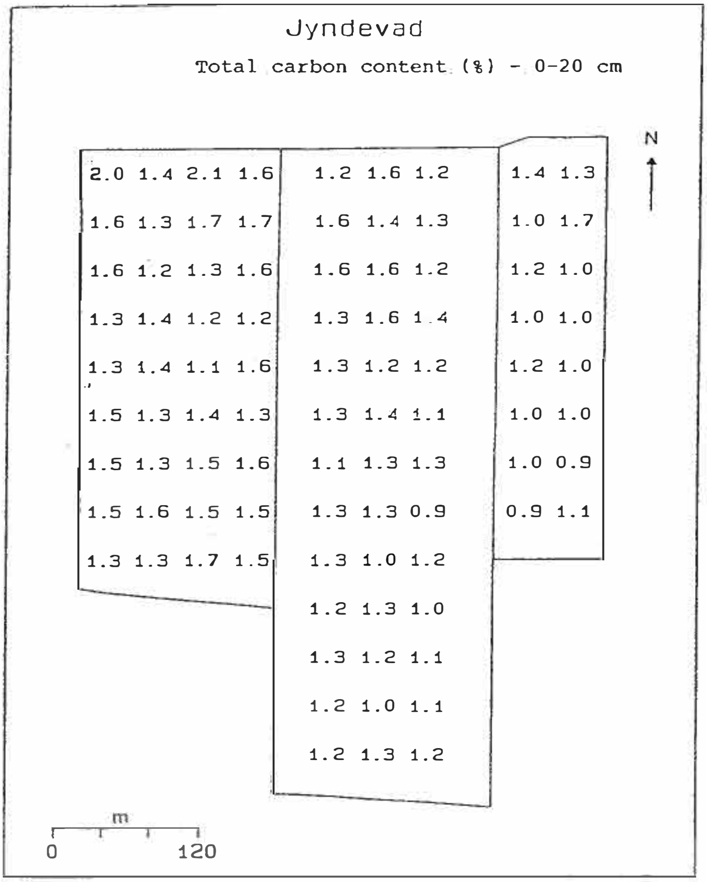

Figure 2: Spatial variation in soil total carbon content (%) at Jyndevad, 0-20 cm depth.

EXPERIMENTAL SET-UP

At each location, crop rotations have been established within fields of about 1 ha. Each field is divided into research and reference areas (Fig. 3). In the reference area the effects of the major system components and their interactions are to be studied.

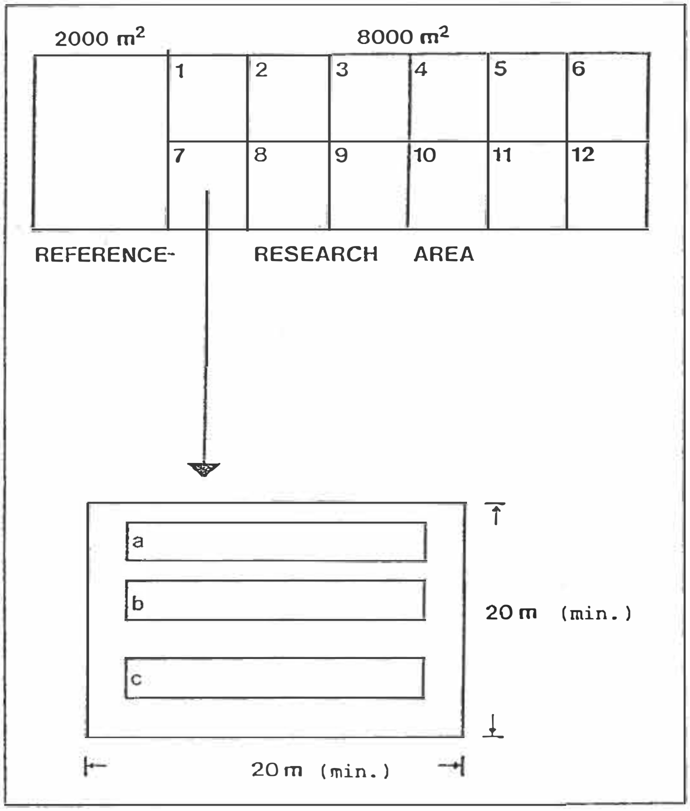

Figure 3: Experimental set-up (schematic) of the research areas.

The cropping programs for the reference areas will be implemented based on the results of the research areas.

In the research area, an analytical approach is to be followed. Selected components of the systems will be studied in detail in factorial experiments. In long-term studies, the research area will be divided into 12 plots each with the possibility of sub-dividing for short-term studies using a split-plot design. The treatments applied must of course be in accordance with the requirements of the particular farming system. An example of a long-term experiment is studies of the optimum use of liquid manure with respect to dosage and application strategy. Similarly, an example of a short-term experiment is variety trials. Long-term experiments can have 4 treatments in 3 replicates.

FARMING SYSTEMS

The farming systems layed out at Foulum and Ødum are shown in Figs. 4 and 5. Organic, integrated and technological systems are placed at each site.

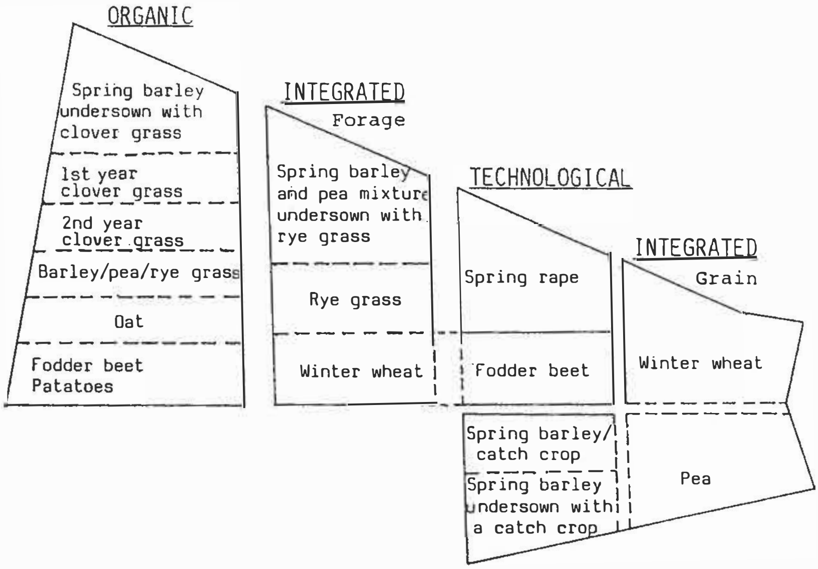

Figure 4: Cropping systems at Foulum 1988.

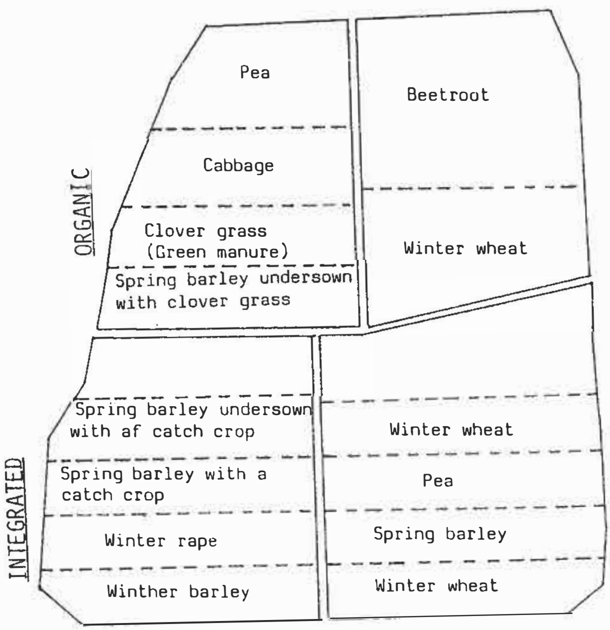

Figure 5: Cropping systems at Ødum 1988.

Organic systems

Fodder crops

At Foulum there is a 6-year fodder crop rotation. Leguminous crops in mixture with other crops occupy half the number of fields. The crops have different growing periods which enables mineralized nutrients to be taught and mechanical weed control carried out. Fertilization is by liquid manure from cattle, and pesticides are not used. The crop rotation (Fig. 4) is based on:

1. Spring barley undersown with clover grass
2. 1st year clover grass
3. 2nd year clover grass
4. Spring barley and pea mixture undersown with rye grass
5. Oats
6. Fodder beet, Potato

Vegetables/grain:

At Ødum there is a 6-year crop rotation with vegetables and grain. All crops are difficult to handle without using chemicals and mineral fertilizers. In the rotation, clover grass serves only as green manure for the other crops. The crop rotation (Fig. 5) is based on:

1. Spring barley undersown with clover grass
2. Clover grass (green manure)
3. Cabbage
4. Peas
5. Winter wheat
6. Beetroot

Projects taking place or planned in the organic system concern

- mechanical weed control
- monitoring fauna
- potato early blight in relation to microclimate
- optimum use of liquid manure

Integrated systems

Grain

At Foulum, Ødum and Jyndevad the crop rotations include grain crops, mainly spring sown. Fertilization is by liquid manure from pigs and ammonium nitrate (KAS) as a supplement up to the optimum nitrogen level. Variety mixtures and resistant varieties are used. Seventyfive percent of the fields are sown to "winter-green crops". The crop rotation at Foulum and Ødum (Fig. 4 and 5) is based on:

1. Spring barley with a catch crop
2. Spring barley undersown with catch crop
3. Peas in 1st crop rotation and rape in 2nd crop rotation
4. Winter wheat.

At Ødum there is also a crop rotation mainly with winter crops (Fig. 5), based on:

1. Winter barley
2. Winter rape
3. Winter wheat
4. Spring barley.

At Jyndevad the crop rotation will be:

1. Potato
2. Rye
3. Spring barley with a catch crop
4. Spring barley undersown with a catch crop.

Fodder crops

At Foulum and Jyndevad there are/will be rotations with fodder crops. The fertilizer used is liquid manure from cattle with KAS used to supplement up to the optimum nitrogen level. The crop rotation at Foulum (Fig. 4) is based on:

1. Spring barley and pea mixture undersown with rye grass
2. Rye grass
3. Winter wheat
4. Fodder beets.

The crop rotation at Jyndevad in 1989 will be based on:

1. Spring barley undersown with clovergrass
2. Clover grass
3. Winter wheat undersown with rye grass
4. Spring barley
5. Maize.

Projects taking place or planned in the integrated system concern

- nitrogen cycles in crop rotations with winter crops
- optimum use of liquid manure in foddercrops
- monitoring fauna.

Technological (conventional) system

At Foulum the crop rotation has only one crop represented each year primarily for reference purpose. Mineral fertilizer and pesticides are used in accordance with normal farming practice. The crop rotation is (Fig. 4):

1. Spring barley
2. Spring barley with a catch crop
3. Spring rape in 1st crop rotation, peas in 2nd crop rotation
4. Winter wheat.

CONCLUSION

No results from the farming systems or the experiments are yet available. Results from the farming systems experiment will be published in annual reports and from the experiments in research reports.

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PLANNING OF INTEGRATED FARMING SYSTEMS EXPERIMENTS IN FRANCE

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INTRODUCTION

All over Europe, farmers are interested in limiting surplus production, of cereals and other crops for both economic and ecologicals reason : prices of agricultural products are decreasing, while prices of inputs are increasing therefore farmers' incomes become threatened. Also, consumers and politicians want a less polluting agriculture through lower inputs of fertilizers and pesticides. As a consequence, it becomes necessary to develop new arable farming systems of which there are two options : organic and integrated. These two systems are not in competition but complementary. Some forms of organic farming can be considered to be a radical approach of integrated farming.

The main interest for integrated farming in France is that it may serve as an effective instrument for extensification. We consider extensification a better solution for overproduction and decline of income, than a so that called market oriented policy based on adaptation of prices to the world market. An EC proposal (23 February 1988) suggested some regulation and financial support for extensification be developped in order to reduce production in Europe. We think that an excellent time to investigate if aiming at lower yields and reduction of inputs could offer perspectives for our agriculture.

DEVELOPMENT OF THE FARMING SYSTEM APPROACH

A report has been produced by the IOBC/WPRS Integrated Farming Systems Group on national experiments on integrated farming systems (Vereijken et al. 1986). Most technical data is available from the on going experiments at Lautenbach and Nagele (this bulletin). As a consequence, a french working group of different institutes (INRA, ITCF, CETIOM, ACTA) has defined two experiments in order to try to develop integrated farming systems.

One of these will be set up on a mixed farm with beef production in the eastern part of France. The second will take place in the south of France near Toulouse, where water supply is low ; it represents a southern European arable farming system including sunflower, winter hard wheat, soybean or winter pea and winter soft wheat. In our view, the main aims of an integrated farming system should be :

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(2) ACTA - 149, rue de Bercy - 75595 PARIS CEDEX 12
(3) INRA - Chemin de Borde Rouge - AUZEVILLE - 31320 CASTANET TOLOSAN
(4) - INRA - SRIV - Domaine de la Motte au Vicomte, B.P. 29 - 35650 RENNES LE RHEU

- to reduce chemical inputs to maintain the integrity of the environment and to reduce costs.
- to maintain soil fertility by higher input of organic matter (mixed farming).
- to maintain a satisfactory level of profits for each crop in the rotation, accepting a possible reduction of yields.

With these aims the integrated farming system can be designed using mainly cultural and biological inputs. Pesticides, fertilizers and fuel are considered as complementary integrated inputs. For soil fertility, the French working group suggests two types of indicators ;
- chemical and physical parameters as soil texture and content of N, P, K and organic matter
- biological parameters as : weed seeds stock, beneficial soil arthropods, earthworms etc...

SIMULATION OF FARMING SYSTEMS

In order to evaluate if these systems are economically viable and to assist farmers' decision-making it is useful to simulate production levels. Moreover, simulation may help to trace the missing links for experiments on IFS.

To test possibilities of extensification, we chose M. Lomagne's farm, of 66 ha, located in the south west of France on typical calcareous clay soil. Rotation of the farm is sunflower, durum wheat, winter pea, soft wheat. Three possible strategies were simulated for development of this farm 1987-1991.

Conventional system is the current farming system of M. Lomagne with his current equipment
Integrated system 1 (IFS 1) : same rotation and equipment, crop pins programs aim at 20 or 30 % less yield through low inputs (Table1).
Integrated system 2 (IFS 2) : same as IFS 1 but with equipment for minimum tillage.

Agricultural prices were based on forecasts made according to the minimum guaranteed quantities. For inputs, an increase of 2 % per year was assumed. In table 1, expected yields are expressed in stable francs during the entire simulation period.

The main objective in the integrated system was to reduce nitrogen fertilisation of cereals and the number of sprays of pesticides. The dosage of nitrogen is calculated with the balance method. Control of weeds and diseases is reduced since we accept some pest and disease development . For sunflower, nitrogen can be totally abandoned. TN 15 variety is used in IFS because of its resistance to *Phomopsis*. For peas and cereals, the farmers' own seeds are used.

In this way the costs of inputs decrease from 2 500 FF to 1 100 FF. Fertilizers account for 50 % of this reduction. Cost reduction is higher for wheat and pea than for sunflower.

Table 2 shows that gross income will decrease 23 % with an integrated farm strategy. However, the gross margin will decrease only by 7 % since costs will decrease substantially, also.

The reduction of mechanization costs, including oil, fuel and repairs seems low but we are dealing with a small sized farm and it is difficult to improve quickly working and well adapted equipment for IFS on so small acreage. Nevertheless, they reduce the differences in direct margin considerable, 4 % yield increase is sufficient to fill this gap.

The integrated cropping strategy seems more promising for winter wheat than for sunflower. The results suggests that it is profitable to optimise the rotation.

TABLE 1
Simulation of farm development based on conventional or integrated strategies : current and desired yield levels

	Yields (t ha^{-1}) Conventional	Yields (t ha^{-1}) IFS 1	Yield reduction (%)
Sunflower	2,4	2	17
Hard wheat	6,5	4,5	31
Winter pea	5	4,0	20
Winter wheat	7,5	5,5	27
Overall			24

TABLE 2
Simulation of farm development based on conventional or integrated (IFS 1 and IFS 2) strategies : average 1987-1991 results over the whole farm (FF ha^{-1})

Average 1987-1991	Conventionnal	IFS 1	IFS 2
Gross income	8 100	6 200	6 200
Direct costs*	2 600	1 100	1 100
Gross margin	5 500	5 100	5 100
Mechanization costs	1 600	1 500	1 400
Direct margin	3 800	3 500	3 600
Direct margin in 1991	3 486	3 164	3 254

* Directs costs :
Gross margin : gross income - direct costs   Direct margin : gross margin - mechanization costs

TABLE 3

Simulation of farm development based on conventional or integrated (IFS 1 and IFS 2) strategies : Average 1987-1991results of winter wheat and sunflower

	WINTER WHEAT			SUNFLOWER		
	Conv.	IFS 1	IFS 2	Conv.	IFS 1	IFS 2
Gross income	7 415	5 463	5 463	7 213	6 013	6 013
Direct costs*	3 302	1 577	1 577	1 597	1 150	1 150
Gross margin	4 113	3 886	3 886	5 616	4 863	4 863
Mechanization costs	1 284	1 350	1 187	1 811	1 750	1 782
Direct margin	2 829	2 536	2 699	3 805	3 113	3 081
Direct margin	2 063	2 138	2 184	3 486	3 086	2 717

* Directs costs :

Gross margin : gross income - direct costs

Direct margin : gross margin - mechanization costs

TABLE 4

Economic results in 1988 in INRA Auzeville (FF)

	W WHEAT		SUNFLOWER		W PEA		RAPE	
Input level	Low	High	Low	High	Low	High	Low	High
Yield T/ha	5,5	7,69	3,39	3,55	3,09	3,94	2,99	3,2
Gross income	5 739	8 024	10 398	10 889	6 050	7 714	6 683	7 152
Direct cost*	1 158	2 556	1 016	1 840	1 320	3 160	1 780	1 702
Mechanization costs	2 060	2 860	2 251	2 635	1 780	2 620	2 350	2 560
Net margin	2 521	2 608	7 131	6 414	2 950	1 934	2 853	2 890
Labour h/ha	6,5	9,25	7,3	8,40	5,55	7,4	7,4	8,5

Results obtained by INRA in the same area, confirm these results. They show that for crops cultivated with two levels of inputs (low level without irrigation and high level with irrigation), low inputs systems could be interesting from an economical point of view. Some crops gave us a very good response to low intensification level (Table 4).

CONCLUSION

The logic following of these promising simulation studies is the set up of farming systems experiments to test the validity of our hypothesis that integrated systems are better, both economically and environmentally, than the current intensified systems.

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INTRODUCTION

The project at Lautenbach was started in the mid seventies as a response to various adverse effects of intensive farming methods. Side-effects of the intensive use of mineral fertilisers and pesticides began to create serious problems. This was accompanied by stagnating or falling farm incomes. The progressive policy of large fields, cropped with very few, mostly susceptible cultivars had facilitated the use of modern farm machinery. However, it also changed the entire agricultural landscape. Removal of hedgerows, vegetation etc. destroyed the habitats for different species of native flora and fauna. More than 360 species are now considered as "lost" or "endangered" through these agricultural activities (KOHLER 1986). Increasing pollution of ground water has now resulted in more legal restrictions in the use of pesticides and fertilizers (ANONYM 1987). Farming society is changing in response to these constraints through a rapid decline in the number of farmers. Within the state of Baden-Württemberg the number of farms has been halved within just two decades (Fig. 1).

To cope with this situation many strategies have been developed. In terms of pest control the concept of Integrated Pest Management (IPM) was initially considered to be the most promising way to reduce pesticide use (STEINER 1965). Examples of the suitability of IPM were demonstrated in apple orchards and greenhouse crops (STEINER & BAGGIOLINI 1988, BRAVENBOER et al 1973). This stimulated interest in similar possibilities for arable crops. Unfortunately, IPM efforts failed to extend beyond supervised control and were thus restricted to "pesticide management" (LUNA et al 1988), mostly directed against single target species. Even within these limitations, farmers found considerable difficulties in adopting IPM programmes. The manipulation of several husbandry techniques to control but a single pest species in isolation from the total farming system does not convince a farmer of its value. This is why IPM did not succeed in becoming a widespread practice in commercial agriculture. At Lautenbach a similar situation occured which illustrates this point. The mycovores, collembola (Onychiurus armatus) had caused serious damage to sugar beet seedlings. Re-sowing and use of insecticides (aldicarb) did not help towards a reasonable seedling emergence. To consider the effects of tillage in controlling collembola was therefore indispensable (EL TITI & RICHTER 1987), but had serious potential consequences to other factors: it determines the intensity of weed emergence (KNAB & HURLE 1988), the mineralisation of organic residues, the occurence of various beneficial organisms, and so on. This example illustrates clearly why an "entire farming system" approach is needed.

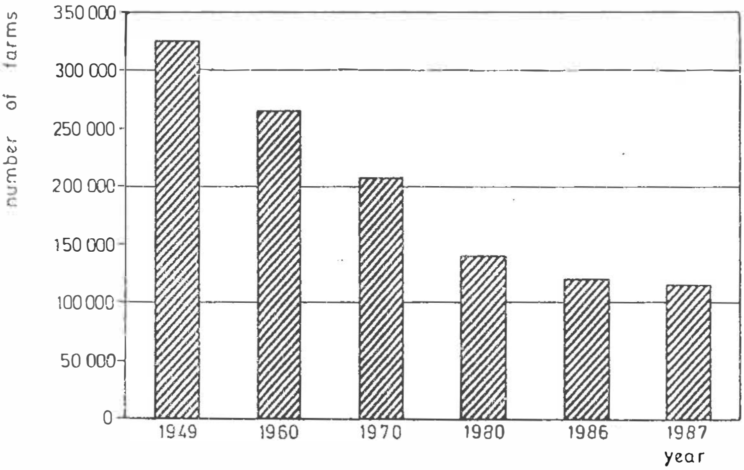

Fig. 1: Numbers of registered farms in the state of Baden-Württemberg/FRG between 1949 and 1987.

The project at Lautenbach was started as the first of its kind in the FRG to study and develop in order to investigate if:

1- farming practices can be integrated to deal with pest problems through improving antagonistic agents.

2- energy inputs, as fertilizers, pesticides and fuel, can be reduced and made efficient more to improve financial returns.

3- the farming system can be made sustainable under current macroeconomical limitations.

4- environmental pollution can be reduced and a reservoir for beneficial wild species established

5- the effects of landscape components on crop productivity can be evaluated in the longterm.

Lautenbach is a private farm of 245 ha located near Heilbronn. Except for 200 pigs no other livestock is kept on the farm. The tenant of Lautenbach, Mr. H. Landes, manages the farm as his ancestry have done since 1869. Major crops are winter wheat, spring wheat, oats, spring barley, sugar beet and legumes (Phaseolus and faba-beans, peas). The farm produces seed of cereals and faba-beans, whereas legumes and sugar beets are grown for industrial purposes. The soils are generally heterogeneous, alluvial sandyloam; brown soil is however, the dominating type. The altitude of the fields varies substantially, mainly between 235-195 NN. The average annual precipitation is 750 mm, and the mean temperature 9,5^{o}C.

MATERIAL AND METHODS

The Lautenbach project is designed to compare the productivity and ecological impacts of two farming systems. One is a low-input, sustainable Integrated Farming System (IFS), which emphasizes the reduction of inputs and improvement of the agroecosystem whilst maintaining a reasonable financial income. The other system is a "conventional" farming system (CFS), and reflects the common type of farming practised at the farm and in the surrounding region.

The Integrated Farming System is operated on ecological principles. It is a concept which exploits natural regulation components of the agroecosystem and incorporates them in the best way possible into farming practice. The components of natural regulation thus comprise the background of the "integrated" approach at Lautenbach. Specific biotic and abiotic factors of the site are well known to influence the breakdown of organic matter, the uptake of nutrients and the activity of soil microorganisms. The diversity and population dynamics of wild animals and plants above and below ground, are governed by these factors. These ecological components determine the success or failure of the entire farming buisness.

Farming operations on the IFS and CFS fields are carried out by the manager himself or by his staff and are his complete responsibility. New implements, techniques or methods can be introduced by agreement of both the project leader and the farm manager. The project leader is responsible for initiating improvements and for coordinating field-scouting and institute experts. He supervises sampling operations, data registrations and so on. Up-to-date field data constitute the basis for cooperative "decision making" as to whether a given field operation should be carried out. Within the process of decision-making the farmer considers mainly the practicability of the recommended method and the expected short-term financial effects.

Different research disciplines are included in the project. The staff involved covers the fields of nematology, entomology, phytopathology and weed science. In cooperation with other state institutes, soil chemical analysis, soil physical measurements and product qualitiy are covered. Economic data analysis is done in cooperation with University institutes.

Experimental layout:

Since seed is produced on the farm no alternative or substitute crops or varieties were allowed. Improvements through crop rotation were accordingly restricted. Crop sequence was the only tool to control pests, diseases and weeds. The total farm area was divided into six field units. In each unit two permanent plots of the same size (4 or 8 ha) were allocated to the farming systems and have been compared since 1978 (Fig.2). The six plot-pairs were located on compareable soil types with the same topography. The same crop rotation is practiced on integrated and conventional fields. The crop sequence adopted is:

winter wheat ⟶ sugar beet ⟶ spring wheat ⟶ faba beans ⟶
sugar beet/winter wheat (alternated) ⟶ oats ⟶ winter wheat.

Six fields totalling 36 ha are farmed in the "integrated" way. They simulate a 36 ha IFS-farm within Lautenbach. The other 36 ha are treated as a "conventional" farm. This farm size corresponds with that which is now common in Baden-Württemberg, it reflects rate of increase in farm size in Baden-Württemberg in the last 10 years.

Monitoring soil nutrients contents, weed species and incidence of diseases and pests, as well as yield components, is carried out in each field plot. Twenty sampling points, randomized within each IFS and CFS plot provide the base-line of the sampling operation. The mean of the 20 points gives the average for each recorded parameter.

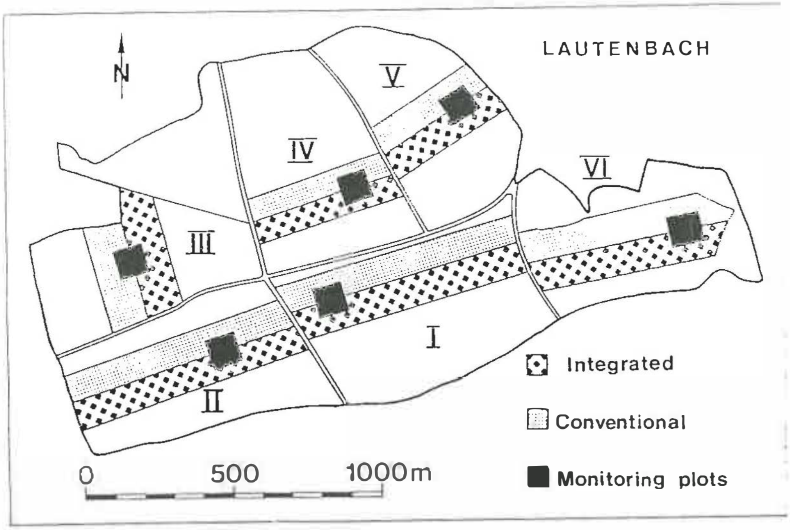

Fig. 2: Design and layout of field plots for "integrated" and "conventional" farming systems at Lautenbach with reference to the monitoring plots.

For assessing the ecological impact a number of bioindicators is used. These include earthworms, soil surface fauna, eudaphic mites, collembola and nematodes, as well as the rate of cellulose decomposition. For this purpose a subplot of 1 ha (Fig. 2, monitoring plots), has been established in each of the 6 field-pairs. The major differences between the two farming systems are listed in Table 1.

In addition to the comparison of farming systems, factorial experiments are included in the Lautenbach project. Various husbandry techniques are studied in randomized plot experiments to evaluate and explain their effects. They indicate whether the farmer can deal with the introduced methods. Different disciplines e.g. soil science, ecology, soil chemistry, entomology are involved in experiments on the effects of soil tillage on soil physical properties, weed seed banks, predatory mites and soil surface fauna and on the effects of undersowing on cereal aphids and their antagonists. The results are used to improve the IFS.

Table 1: Comparison of the main cultural measures used in the "Integrated" and "Conventional" Farming Systems in the Lautenbach project.

	I F S	C F S
Crop rotation	60% cereals, 25% sugar beets, 15% legumes	60% cereals, 25% sugar beets 15% legumes
Soil tillage	tine loosening + rotory incorporation - non-conversion -	ploughing
Sowing		
Sugar beets	45cm interrow/20cm seed space	45cm interrow/20cm seed space
Cereals	double-rows 6 cm within 24 cm between	drilling 15 cm
Faba-beans	45cm interrow, 5cm seed space	drilling 30 cm
Cultivars	same variety	same variety
Fertilisation		
$Ca/K_2O/P_2O_5$	according to soil chem. analy.	according to soil chem. analy.
Nitrogen	according to N-min, but reduced (25%)	according to N-min optimal supply (recommended dose)
Control		
Weeds	mechanical / herbicides	herbicides
Diseases	fungicides at high incidence	fungicides
Pests	insecticides only at high thresholds	insecticides
Hedgerows, Shelterbelts	included	not considered
Field margins	native flora accepted	native flora mowed
Fieldedge-attractants	included	not considered

Transfer of knowledge:

A perfect IFS does not exist. IFS will be continously evolve and require adjustments, changes and improvements. Even so, farmers need to share this environmentally oriented farming alternative. For 6 years the 6 plot pairs cropped winter/spring wheat, sugar beets and legumes have been subjects of various on-farm demonstrations. Field discussions with visiting farmers contribute immensely to improving the system and allow the specific interests of farming society to be incorporated. The increasing number of visitors (Fig. 3) reflects the enthusiasm of practical farmers to have multidisciplinary demonstrations and information. However, the degree of acceptance or adoption by visitors from these demonstrations can be not be measured.

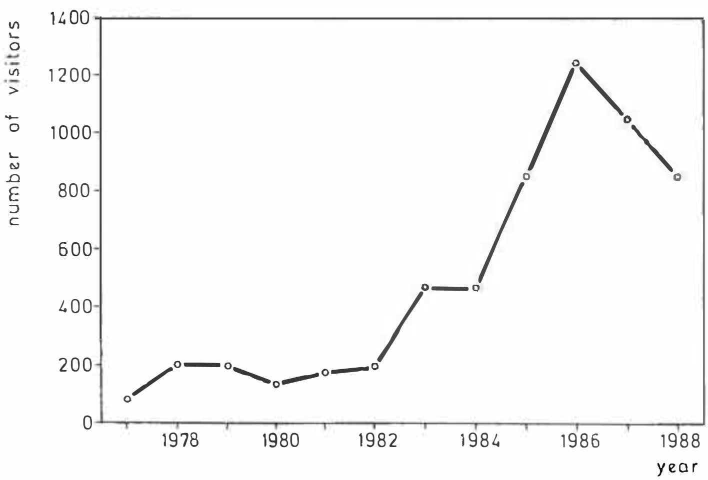

Fig. 3: Numbers of visitors to the Lautenbach project 1977-1988.

Educating and training in the official extension services are important features of the Lautenbach results to farmers. State officers for plant protection are trained once a year in selected problems. Methods and implements are practised in the field. It is, however, to be pointed out, that there is a big gap between the real "needs" to achieve reasonable training and the "offer" given.

RESULTS

The Lautenbach project is now in its 11th year. Accumulated data are evaluated on the basis of a complete rotation of 6 years. The first rotation ended 1983; the second is now beginning its last year.

Soil chemical analysis (Fig. 4) show that the two systems hardly differ in soil mineral nutrient contents.

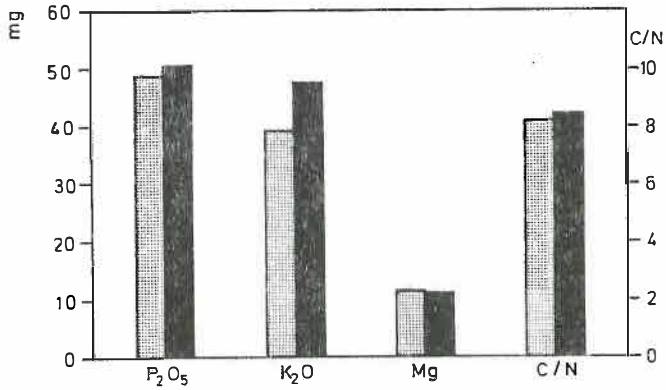

Fig. 4: Major soil nutrient content in "integrated" and "conventional" fields at Lautenbach.

The mineral fertilizers input in integrated and conventional systems is shown in Table 2.

Table 2: The annual average fertiliser (N, P, K) input in "integrated" and "conventional" farming systems at Lautenbach (mean of all fields over 10 years).

C R O P	I F S			C F S		
	N	P	K	N	P	K
Winter wheat	116	95	187	155	98	187
Spring wheat	129	21	113	175	39	113
Sugar beets	144	54	120	162	61	120
legumes	16	86	177	20	86	194

There has been little difference in P and K inputs between IFS and CFS, mainly due to the education process of the farm manager during the first rotation years. However, significant reductions were achieved after 1984 (beginning of the second rotation). Because of its effects on diseases and pests, there has been a significant reduction in the N-input in the IFS throughout the project (Fig. 5).

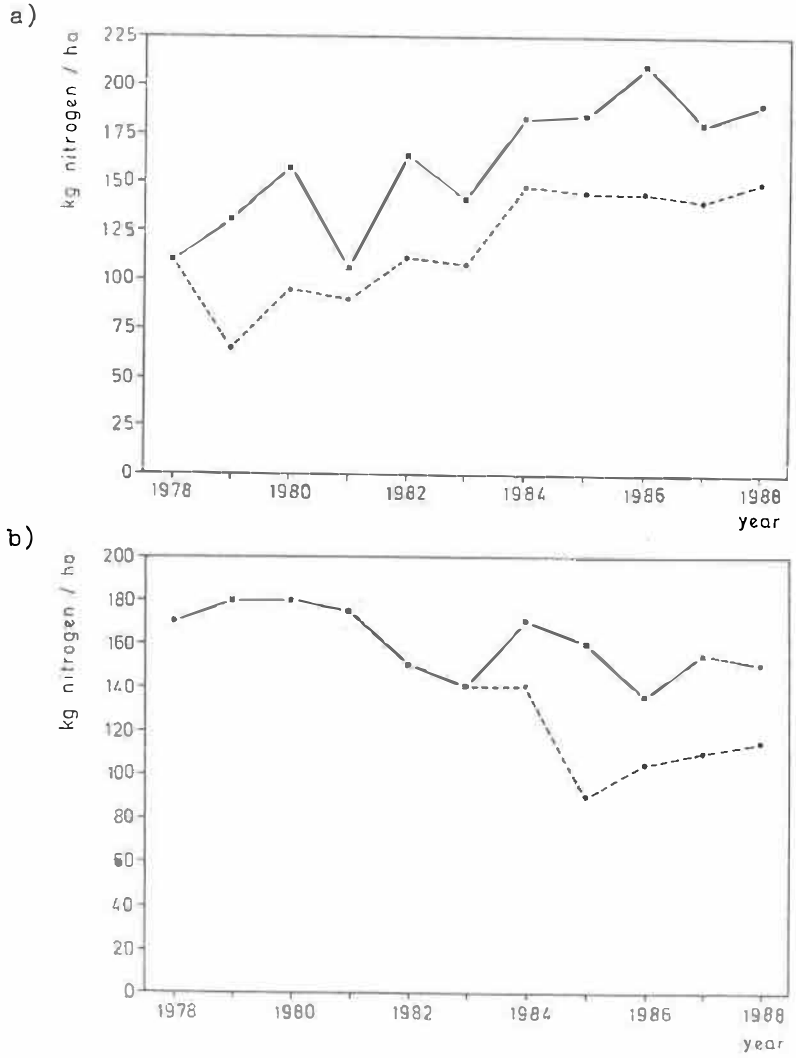

Fig. 5: Annual nitrogen inputs to "integrated" and "conventional" winter wheat (a) and sugar beet (b), between 1978-1988.
•-----• integrated •——• conventional

The incidence of pests, pathogens and weeds was significantly different between the systems. In winter wheat the incidence of major diseases such as the stem base diseases, powdery mildew and leaf spot (Septoria) tended to be lower in the IFS than in the CFS. This was also true for most pests, including wheat bulb fly (Delia coactata), leaf miners (Agromyza spp.), stem borer (Chlorops pumilionis), cereal beetles (Oulema spp.), cereal aphids (Sitobion avenae and Metopolophium dirhodum) and cereal nematodes (Heterodera avenae and Ditylenchus dipsaci). However, weeds showed on average higher densities in the IFS than in CFS fields (Table 3).

Table 3: The effects of integrated farming on diseases, pests and weeds in winter wheat.

	on IFS in fields compared with CFS
A: Diseases	
Stem base disease	-
Powdery mildew	-
Leaf blotch disease (Septoria)	+
Fusarium blight	+
Helminthosporium tritici repents	-
B: Pests	
Wheat bulb fly	--
Ditylenchus dipsaci	--
Heterodera avenae	--
Cereal aphids	--
Leaf minors	-
Cereal beetles	-
C: Weeds	
Blackgrass	+
Broadleaf-weeds	+
Quack gras	+
Thistle	-

(-) slight reduction (--) significant reduction
(+) slight increase (++) significant increase

In sugar beet seedling emergence was greater (5-15 %) in the IFS than in the CFS in 9 of 10 years. This can be related to reduce losses from soil pests, e.g. leather jacket (Tipula spp.), wireworms (Elateridae), millipeds (Blaniulus guttulatus) and collembola. Sugar beet attack by mangold fly (Pygomia hyoscyami) and aphids (Aphis fabae) show the same trend.

The effects of IFS on the net physical yields (net marketable product weight/ha) differs between crops (Table 4).

Table 4: The average of physical yields of five crops grown on "integrated" and "conventional" fields between 1984-1988.

	t/ha $\bar{x}$ 1984-1988 IFS	CFS	Deviation to CFS in %
Winter wheat	6,00	6,5	- 8 %
Spring wheat	6,01	6,78	- 11 %
Oats	5,39	5,35	+ 1 %
Sugar beets	64,53	63,45	+ 2 %
Faba-beans	4,40	4,30	+ 2 %

Winter and spring wheat in IFS failed to out-yield crops in the CFS. However, oats, sugar beet and faba beans in the IFS gave slightly higher yields. Reductions in chemical inputs did not reduce the yields of these three crops.

The financial returns of both farming systems are summarized in Table 5. The allocated costs for almost all the crops were less in the IFS than in the CFS. Reduced inputs winter wheat resulted in lower physical yields but there was no significant difference in the total returns. In contrast higher income was achieved by IFS. Spring wheat responded similarly but IFS tended to generate slight losses. Sugar beets and faba beans in IFS improved the gross margin, but the difference was not significant.

Table 5: The mean value of different parameters* for IFS and CFS between 1984-1988, related to the major crops at Lautenbach.

	Total returns in DM/ha		Variable machinery costs DM/ha		Pesticides costs DM/ha		allocated** costs DM/ha		Gross*** margin DM/ha		Labour-Requirement h/ha/years	
	IFS	CFS	IFS	CFS	IFS	CFS	IFS	CFS	IFS	CFS	IFS	CFS
W. wheat	2856,92	3104,50	196,3	232,59	174,97	358,18	1104,88	1388,32	1753,29	1716,18	6,53	7,81
S. wheat	2915,35	3265,31	181,94	219,93	185,54	343,31	856,09	1089,42	2059,26	2175,90	5,77	7,09
Oats	2192,76	2176,70	171,58	185,75	84,22	81,53	708,75	643,83	1484,02	1532,88	5,65	5,85
Sugar beets	6292,51	6222,64		385,22	287,97	342,83	1296,64	1403,18	4995,87	4819,46	15,84	13,77
Faba-beans	3220,69	3184,16	191,11	185,78	55,53	153,70	811,59	919,56	2409,10	2264,66	6,56	6,13

* fixed costs are excluded, since no significant differences between the systems, in building, tenancy ...etc.

** total allocated costs include: seeds, fertilisers, pesticides, variable machinery costs, insurances and interest value.

*** gross margin = total returns - allocated costs.

The overall farm economics can be globally summarized as follows: From the means of all crops in IFS there was no reduction in physical yields, slight reduction in the labour demands (-3 %), significant reduction of the variable machinery costs (-7 %) and pesticides (-36 %), and a slight but not significant increase in the gross margin (4 %).

Pesticide input in the IFS was generally less in all crops. On average for all crops, a significant reduction of one third active ingredients applied was achieved (Fig. 6), less mineral fertiliser was also applied to the IFS, significantly so since 1984. Thus the two major sources of environmental pollution have been substantially reduced in the IFS.

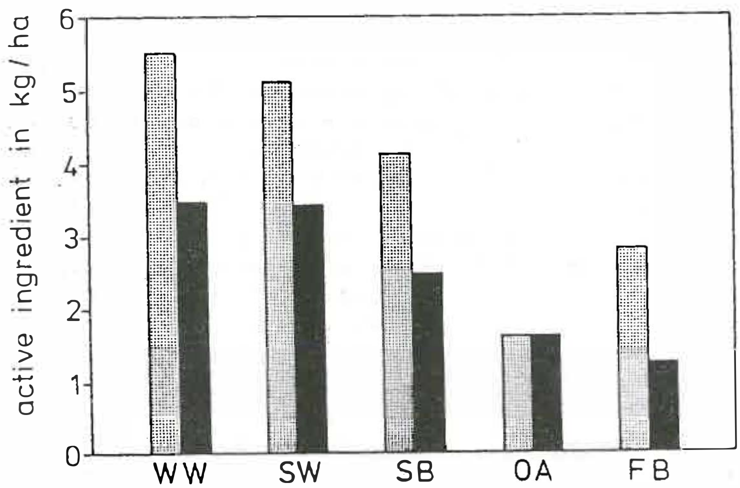

Fig. 6: Average input of active pesticide ingrediants in "integrated" and "conventional" arable crop systems at Lautenbach between 1984-1988.

■ integrated ▒ conventional

Ecological data from both farming systems indicate highly significant improvements within the agroecosystem of the IFS. The biomass of earthworms in the IFS has been up to six times greater than in the CFS; this was found in almost all fields during the ten-year experimental period. Soil surface fauna responded to the IFS through increased species diversity and numbers caught in pitfall traps. However, some species were more prevalent in the CFS fields. Higher densities of most of the euedaphic faunal groups occured in soils of IFS. This was true for mesostigmatic mites, collembola and predatory nematodes (Mononchidae).

Ecological niches as hedgerows and field margin vegetation have been increasing in IFS throughout the experimental period on the farm. New hedges on field boundaries now occupy about 7 km on the farm.

One of the considerable advantages of IFS is improvement in the soil physical structure. Erosion of IFS soil has been decreased through improved water permeability, bulk density and aggregate stability (EL TITI, 1988).

DISCUSSION

The main objective of the Lautenbach project is to demonstrate on a commercial farm an integrated farming system. Accordingly, integration means simply also the deliberate encouragement of natural regulation agents to prevent phytophagous species from reaching "pest status". This present farm structures do not allow the most desirable changes to be made. The lack of livestock in Lautenbach and specialization in arable crops have been serious constraints in making the most efficient use of other components of the natural regulation, as it is the case in mixed farm rotations. Despite this fact there has been great improvements among many ecological elements. Making use of crop sequences, minimizing soil mechanical disturbances, growing catch crops, and undersowing to improve nutrient cycles or to bind nitrogen have obviously contributed to the process of crop production without financial losses. The fact that Lautenbach is a seed-producing farm has made it rather difficult to tolerate, for instance, weeds or crop volunteers. This will not be the case on most of other farms. More options and close cooperation with the farmer is an extremely important aspect in development of IFS. It gives researchers and extension authorities realistic informations about what farmers generally require in order to convert IFS-knowledge into field operations. The farm manager as the operational brain of the farming buisness has, unfortunately, been dismissed from much modern research.

In order to convince the farmer who has been educated and trained in conventional production methods, demonstration farms are indispensible. Research stations and governmental advice cannot persuade an eager farmer of the value of IFS as his colleagues can do, particularly if his colleagues practise alternative farming methods on their own farms. This is one of the strong points in in the Lautenbach project; that is a private farm. On the other hand, research leaders have to accept compromises, which might not suit their research aims in ideal way.

A serious difficulty is the management of both farming systems by the same manager. If he is convinced that, for example, adjusted nitrogen input in the IFS will improve yield, it is unrealistic to expect him not to use this knowledge on the CFS. This was the case at Lautenbach in dealing with phosphorus inputs, reduced herbicide doses and so on. However, the advantages of having the comparison of both farming systems at the same growing site compensates for these disadvantages.

The integrated approach of Lautenbach has not solved all problems. However, it is a contribution towards an ecologically sound way of agricultural production. Growing crops, wild vegetation and faunal groups must all be handled as components of an agroecosystem. Realistic compromise rather than maximal expectation will help to overcome present problems. The farmer at Lautenbach has understood his role in synthesizing a system on farmland. The synthesis requires multidisciplinary information, which has not been the subject of modern research. Exactly this is what is urgently needed: a interdisciplinary approach in education, training and extension.

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PREPARING FARMING SYSTEMS RESEARCH IN TUSCANY, ITALY

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INTRODUCTION

Since the second world war, development of agricultural technology has shown an exponential trend, as have other industries. In Europe, it has solved the problems of food production, but introduced increasing concern about environmental quality. This concern has arisen from the increased use of persistent and mobile pesticides and fertilizers, which pollute soil and water resources.

There is an increasing public awareness of the risks to the environment and public health, in particular concerning residues of atrazine, molinate and bentazone in drinking water in North Italy. Quantities of these residues are well above the current EC-acceptable thresholds. This situation is stimulating policy makers to consider changing of agricultural systems to combine sustainable food production with a balanced agroecosystem. Integrated and organic/biological agricultural systems could create a better environmental quality than conventional agriculture (Vereijken et al., 1986; El Titi, 1986; Vereijken, 1989).

Recently in Tuscany, especially in areas with low productivity, groups of farmers have begun to adopt organic/biological systems. However, there is little chance that this approach will become generally an alternative to conventional agriculture. Tuscany is composed for 68% of hilly country, for 24% of mountains and for 8% of plains, and so only a small area is suitable for further intensification. Landscape preservation is of particular importance since the regional economy is dependent on tourism. In this respect environmental quality has a quantifiable economic value. Because of these factors new farming systems have to be developed which improve energy utilization through a considerable reduction in the input of chemicals. The aim can only be achieved by large- and small-scale adjustments of agrotechnology based on a sound ecological knowledge.

This approach got some attention already in research (Bonari et al., 1987; Massantini et al., 1987). In cooperation with members of the IOBC Working Group "Integrated Arable Farming Systems" the philosophy of integrated production has been explained in seminars at Greve in the Chianti region (Vazzana, 1986) and at Florence (1988) and has been discussed with public institutions and extension service organisations.

Since the new EC agricultural policy aims at the control of overproduction through reducing guaranteed prices, integrated agriculture is seen to sustain or even improve the income of farmers by reducing costs. It could also help to maintain employment in agriculture. It appears therefore that intensification of agriculture is no longer a long term policy. The growing demand for a European market with high quality products, the increased sensitivity of public institutions involved in agricultural policy and work done recently to develop the integrated approach have all been combined to enable the foundation of an experimental farm. This is intended to be an experimental and dynamic example of comparison between integrated ad conventional agriculture. The results should eventually be taken up by leading farmers in different areas.

PILOT FARMS AND EXPERIMENTAL LAY-OUT

The planned experimental pilot farm, Azienda di Mondeggi-Lappeggi, belongs to the Province of Florence. It is located 17 KM far from the town, in a hilly area in a typical Tuscan landscape. The total farm area is 191 ha, of which 17.5 ha is arable land (clay), 59.5 ha is with specialized olive orchards, 36.5 ha are specialized vineyards, 74.5 ha is woodland and 1 ha is for forage cropping. The arable area is divided into wheat monoculture (1/3 area) and wheat in rotation with sunflower (2/3 area).

The current manager will be responsible for the conduct of the project. Two full time scholarships will become available for postgraduated students who will act as intermediates between the farm manager and the research coordinator during the first two years. They will monitor crops and carry out plot experiments. A scientific committee with researchers from the Faculty of Agronomy of Florence University, Research Institutes and from public institutions will guide the development and testing of the integrated systems.

Following a seminar held in Florence in May 1988, several individual farmers declared their intention to convert to integrated agriculture. Because of the impossibility of setting up experimental farms in the different pedoclimatic and social areas of the region, we think that adoption and development of integrated systems can best be achieved through direct cooperation with sympathetic farmers, who will thus become examples within their own areas.

Two farms are to be converted in this way: the first, Azienda il Poggio, is located at Rignano sull'Arno (FI) (64 ha on sandy-loam and clay soil comprising 40 ha arable land, 4 ha olive orchards and 20 ha vineyards). The farm is also located in a typical Tuscan landscape. Part of it is converted to biodynamic farming. The owners are very much interested in reducing chemical inputs on the other part of the farm also. Experiments are planned on the use of sequential sampling for integrated weed control in wheat and soybean, on undersowing of wheat, and on examining the significance of the natural flora and crop pest and pathogens.

The second farm, Azienda Cipolla, is located at S. Quirico d'Orcia, (SI), (300 ha comprising 280 ha arable land of which 250 ha are on clay and hilly, 30 ha are on a plain and 20 ha is pastureland, 5 ha is woodland and 1 ha is olive orchard). Clay soils dominate the farm. The owner was originally practicing intensive *durum* wheat cultivation, with a high input of fertilizers, herbicides, insecticides and fungicides. Since 1985, with the introduction of leguminous crops into the rotation, he reduced the use of N-fertilizers and herbicides and stopped using insecticides and fungicides. In 1987, crop rotation was set up on part of the farm with leguminous undersowing and green organic manure. This part is to be converted into an integrated system. The aim is to obtain high quality production of *durum* wheat and leguminous crops. The motivation is mainly preservation of soil fertility and environmental quality, but also reduction of costs of intensive cereal cultivation. The farm is in an area of intensive agriculture (wheat monoculture) and it could thus have a favourable influence on neighbouring farmers.

On the pilot farm, at Azienda Mondeggi-Lapeggi, we have to do a preliminary study to obtain more information about the current agroecosystem and to analyse current farming methods in order to plan the experimental lay-out. At this farm the aim will be to compare integrated and conventional agriculture at the farm level. In the first stage only the arable part of the farm will be included. Future work will include also the vineyards and olive orchards which are the main sources of income for the farm. Interdisciplinary research projects will take place, mainly on the natural flora and fauna, soil tillage techniques, effects of reducing nitrogen fertilizers, undersowing and green manure and weed and pest control. The systems will be improved according to research results and following agronomical, ecological and economical evaluation. Experiments will be done on new technologies before incorporating them into the integrated model.

The best results from the research at the pilot farm will be evaluated at a practical level to test the possibilities for large scale introduction on the other two farms. During the first stage knowledge transfer will be greatly facilitated from the pilot farm belonging to a public institution and the personnel included being mainly from University and Research Organizations.

CONCLUSIONS

Integrated farming systems as investigated and practised in other countries such as the Netherlands, West Germany and Switzerland are not universally applicable. Socio-cultural and economical differences between countries and regions demand that there must be an integration of components of the local agroecosystem in these models. In Tuscany it is important that economic output should be maintained. Experiences from other countries will help us to evaluate our results. Establishing the initiative in Tuscany took a long time and the experimental farm will probably be difficult to manage. Even so we are convinced that this is the only way to increase our knowledge of the relationships between human activities and agroecosystems and to involve more and more farmers into integrated farming systems.

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Research on Integrated Arable Farming and Organic Mixed Farming in the Netherlands

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As doubt is growing on the perspectives of current agriculture, interest is increasing in alternative systems of production. As a result, many new research activities have been started, especially in the field of plant production. In Europe, a working group of the International Organization for Biological Control (IOBC) is trying to develop integrated arable farming systems inspired by the aims and methods of integrated pest management (IPM) (Vereijken et al., 1986). The two oldest projects are the Lautenbach experimental farm near Stuttgart, West Germany (El Titi, 1989) and the Nagele experimental farm in The Netherlands. The latter study is subject of the current paper, considering 9 years of scientific coordination by the author (1979-1987).

Nagele experimental farm

Research of this national experimental farm for the development and comparison of alternative systems started in 1979. The farm is situated near the village of Nagele in the NorthEastpolder, three to four meters below sea level on heavy sandy marine clay (24 percent lutum). The size of the farm is 72 hectares. Three farming systems have been studied: organic, integrated, and conventional. They are run on a commercial basis by one manager and four co-workers. The organic farm is managed according to the biodynamic method, which is one of the organic systems practiced most in Western Europe to date. It is a mixed farm of 22 hectares, with 20 dairy cows and a 11-year rotation, including 55 percent fodder crops. Its main objective is to be self supporting in fertilizers and fodder. No pesticides are allowed. The conventional and the integrated farms are concerned exclusively with arable farming. They are each 17 hectares and have the same 4-year rotation. The conventional farm, which serves as a reference, seeks to maximize financial returns. The integrated farm should produce a satisfactory financial return, but is also aimed at minimal input of fertilizers, pesticides, and machinery to avoid pollution of the environment and save nonrenewable resources. So it may be characterized as an intermediate system.

The research on the farms has three objectives: (a) development of the organic mixed farm and the integrated arable farm in theory and practice, (b) evaluation of the results of the systems, based on their specific aims and (c) comparison of the results of the experimental systems with those of the conventional reference system.

The aim is not to choose between development or comparison of systems but to consider them both as necessary. The experimental systems have to be developed fully before they can be judged on their feasibility and viability, in comparison with conventional agriculture. In a previous paper, the initial results of farming and research were presented relating to animal husbandry, crop growth and yield, soil cultivation and weed control, pest and disease control, quality of products, farm economics, effects on nature and the environment (Vereijken, 1985). One of the most crucial questions in organic farming, that of how to maintain soil fertility, was treated separately (Vereijken, 1986). Herein, the latest research results are evaluated, with special emphasis on development of farm management, inputs of fertilizers and pesticides and economic results. Based on these results, the perspectives of the two alternative farming systems can be discussed.

Farming methods and techniques

Crop rotation. An appropriate crop rotation can be very effective in controlling pests, diseases and weeds and in maintaining soil fertility. In conventional agriculture, the chances for a good rotation have been strongly reduced, because most farming holdings in The Netherlands are small and farmers have to grow high yielding crops in an intensive way, facing increasing production cost and decreasing returns for their products.

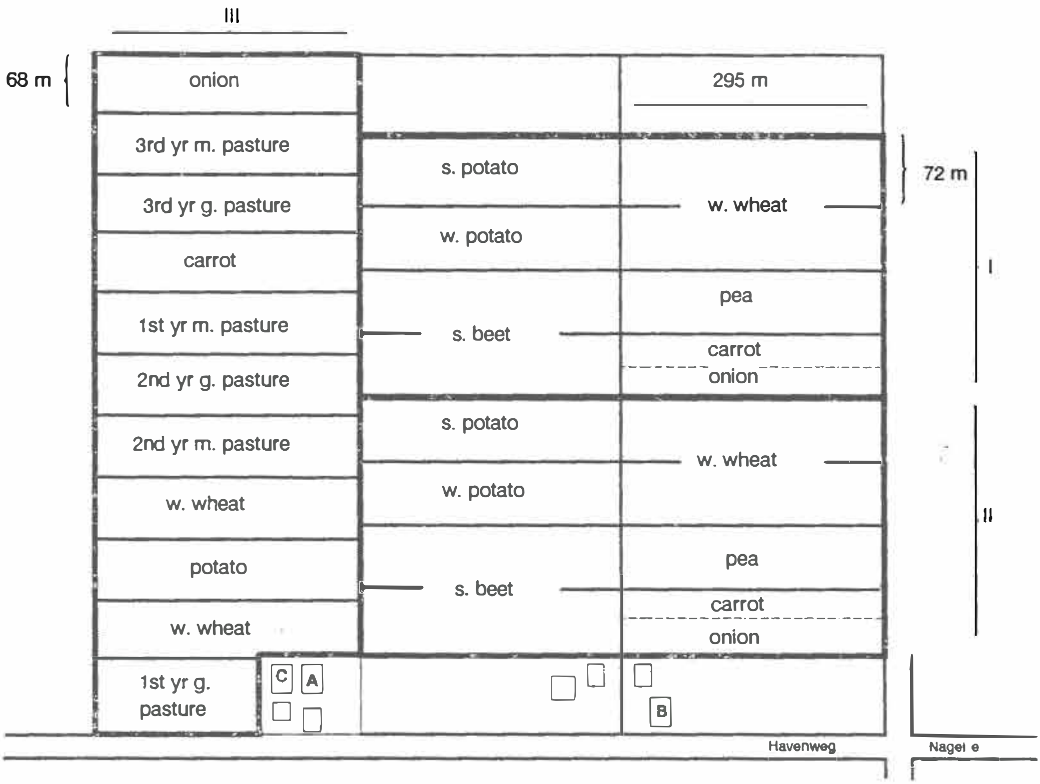
For this reason, the integrated system had the same crop rotation as the conventional: potato - variable - sugar beet - winter wheat (Fig. 1). The crop choice for the variable-year crop field depended on the market situation. Since 1985, peas were grown on half of the field and onions and carrots on a quarter each. A longer rotation would have offered a better barrier against soil-borne pests and diseases, but it also would have been less profitable than the current 4-year rotation.

By contrast, the mixed character of the organic system offers excellent opportunities for a diversified and sound rotation. Perennial pastures with grass and clover suppress weeds, restore the soil structure, and increase the organic matter and nitrogen content of the soil. Moreover, a high proportion of grassland in the rotation reduces the cropping frequencies of the marketable crops, such as potato and cereals. As a result, the pressure of soil-borne pests and diseases is kept to a minimum. Until 1985, fodder cereals, such as winter barley and oats, were also part of the rotation. However, their low gross margins had a negative impact on the economic results of the organic farm. Therefore, they have been replaced by high-yielding crops, such as onion and carrot. Consequently, a limited amount of supplementary feed has had to be purchased since 1986. At the moment, the rotation is potato - winter wheat - carrot - 3-year mowing pasture (alfalfa, red clover, English rye grass) - onion - winter wheat - 3-year pasture (white clover/grass mixture) (Fig. 1). This crop sequence was based especially on alternating positive and negative influences on the structure and the nitrogen reserves of the soil.

Fertilization and crop protection. As is usual in Dutch arable farming, fertilization on the conventional farm was mainly of a mineral nature. Organic manure, preferably solid chicken manure, was applied only to the wheat stubble land to supply organic matter. On the integrated farm, fertilization was mainly organic; mineral fertilizers were used only as a complement. In this system, crops were moderately supplied with nitrogen to avoid abundant leaf development and, as a result, high disease susceptibility. Liquid chicken manure was applied right before the sowing of sugar beet and the planting of potatoes and was plowed under immediately to achieve a maximum nitrogen effect.

In conventional agriculture, green manure is applied to improve the soil structure. On the integrated and organic farms, green manure crops also were grown to fix the nitrate that had been left behind by the main crop or that had mineralized after harvest. Thus, green manure crops served to prevent nitrate leaching.

Fig. 1. Experimental farm "Development of Farming Systems" in 1989.



I - Conventional farming system with a 4-year crop rotation: potato (0.5 ware, 0.5 seed) - 0.5 pea, 0.25 onion, 0.25 w. carrot - sugar beet - winter wheat (17 ha).

II - Integrated farming system with the same rotation as I (17 ha).

III - Biodynamic ley farm with 20 dairy cows and a 11-year rotation: ware potato - winter wheat - carrot - 3-year mowing pasture with Italian rye grass + lucerne + red clover - sowed onion - winter wheat - 3-year grazing pasture with white clover + English rye grass (22 ha).

a - Office of scientific coordinator dr. F. Wijnands at Havenweg 6, Nagele. Post to PAGV, P.O. Box 430, 8200 AK Lelystad, tel. 03200-22714.

b - House of the farm manager.

c - Loose-housing for 25 cows at the biodynamic farm.

On the organic farm, only organic manure from the same farm was used. Clover was the main source of nitrogen in the farm cycle. After being consumed as protein by dairy cattle, nitrogen was collected in the loose-housing as stable manure. Together with the other nutrients, nitrogen then was distributed over the various crops, as required. Because products are sold off the farm, soil reserves of phosphorus and potassium were depleted gradually (Vereijken, 1986). This was compensated by purchasing straw and roughage (from natural areas) and some concentrates (partly from conventional origin).

In conventional agriculture, crop protection is chiefly of a chemical nature. On the integrated farm, however, pesticides were used only as a last resort. Chemicals that are known to be highly toxic, persistent, or mobile were avoided. Weeds, diseases, and pests were controlled mainly by using resistant varieties, lowering of the nitrogen-dressing, mechanical weed control, use of appropriate sowing times and sowing distances, etc. (Vereijken, 1989a). On the organic farm, ample rotation was indispensable for the prevention of weeds, pests, and diseases because chemical control was prohibited. In both experimental systems, some loss in yield caused by weeds, pests, and diseases was accepted.

Cropping systems based on these principles cannot be perfect. Regular observations and reports on management and crop reactions are needed to track imperfections. Ideas from outside the experimental farm (practices, extension, and research) also can improve cropping programs. The fundamental choice of natural practices on the organic farm often called for unusual and risky cropping measures. If successful, they could be introduced on the integrated farm, too. Thus, the biological system serves as a source of inspiration and a pioneer for the integrated systems.

Results of farming and research

Economics and the environment represent the two main criteria for the social acceptibility of the three production systems. The inputs of fertilizers and pesticides were important indicators of the environmental impact. The economic viability was indicated especially by net surplus and labor returns. Because of considerable changes in the management of the systems since 1984, only the latest results are presented (1985-1987).

Table 1. Average farm economic results of the conventional, integrated and organic farming systems, 1985-1987.

	Economic Results (Dutch guilders/hectare) Conventional	Integrated	Organic
1. Returns from marketable crops	6,190	6,250	12,370
2. Returns from grassland and fodder crops	-	-	8,630
3. Total returns	6,190	6,250	10,500
4. Labor cost*	2,310	2,280	5,800
5. Contract work	1,020	1,020	1,290
6. Equipment and machinery	1,560	1,630	2,310
7. Total operation cost (4 to 6)	4,890	4,930	9,400
8. Land and buildings	1,290	1,290	2,630
9. Cattle and fodder	-	-	1,820
10. Fertilizers	450	290	-
11. Seeds	690	790	470
12. Pesticides	690	260	-
13. Other cost	610	610	900
14. Total cost (7 to 13)	8,620	8,170	15,220
15. Net surplus (3 minus 14)	-2,430	-1,920	-4,720
16. Labor returns (15 plus 4)	- 120	360	1,080
Technical and economic data			
17. Marketable crops (ha)	17	17	10.7
18. Grassland + fodder crops (ha)	-	-	11.4
19. Livestock units	-	-	21.8
20. Number of labor units	0.7	0.7	1.7
21. Standard holding units (SHU) per ha	6.2	6.2	5.5
22. SHU per labor unit	149	152	68

* 27 guilders/hour was the normal gross reward for the farmer's own labor in Dutch agriculture during 1985-1987.

Total returns of the organic farm appear to be considerably higher, because of the high premiums on standard product prices (Table 1). Marketable organic crops clearly have higher returns than grassland and fodder crops. However, the total production cost was much higher than on the conventional and integrated arable farms, especially in labor, buildings, and cattle/fodder, which renders by far the lowest net surplus. Inspite of this, returns on labor on the organic farm were highest, although insufficient compared to other professional groups. The integrated farm hardly differed from the conventional farm in total returns and total operation costs. However, the integrated farm gave considerable savings of expenses in fertilizers and pesticides. As a result, the integrated farm achieved a 480 guilders per hectare higher net revenue. The three farms were hardly different in intensity of soil use (standard holding units per hectare). Labor productivity of the organic farm, however, was less than half of those of the two other farms (standard holding units per labor unit).

Table 2. Fertilization and nitrate-nitrogen content of the drainage-water in the three systems averaged for 1985-1987.

	Conventional	Integrated	Organic*
		Kilograms/hectare	
K as fertilizer	135	50	-
K in organic manure	75	80	155
Total	210	130	155
P as fertilizer	10	-	-
P in organic manure	40	55	20
Total	50	55	20
N as fertilizer	135	55	-
N in organic manure	80	125	115
Total	215	180	115
		Milligrams/liter	
Nitrate-N in drainwater	11.2	9.8	4.3

* Organic manure of the own farm

On the integrated farm, an important shift has taken place from mineral to organic fertilization (Table 2). Compared to the inputs on the conventional farm, total inputs of potassium and nitrogen were less and the total input of phosphorus was equal. On the organic farm, a large quantity of potassium was brought into circulation by fodder crops and cows. However, phosphorus and nitrogen fertilization here was by far the lowest.

On the organic farm, relatively little nitrate is leached, as shown by the analysis of the average drain water contents (Table 2). Nitrate leaching on the integrated farm remained below the conventional, notwithstanding its principally organic form of nitrogen supply. Apparently, the resulting higher nitrogen mineralization after harvest was recovered successfully by green manure crops. Untill now, only the organic farm could clearly meet the standards of the Dutch Ministry of Environment for shallow waters (10 milligrams of nitrate-N per liter). In fact, the drainwater of the organic farm was so clean that it can also reach the European Economic Community guidelines for the maximum admissable nitrate content of drinking water (5.6 milligrams of nitrate-N per liter = 25 milligrams of nitrate per liter).

Table 3. Balance sheet of N, P, K nutrients on the organic farm in 1986.

	N	P	K
		kilograms/year	
Outputs			
84 tons milk with 33.8% protein	455	75	125
4,5 tons fresh weight of cows and calves	115	35	75
4 ha cereals, 5,5 t/ha	100	30	85
1 ha potatoes, 45 t/ha	80	25	155
1 ha onions, 50 t/ha	30	20	145
1 ha carrots, 60 t/ha	55	15	180
2 ha peas, 3.5 t/ha	245	25	35
1 ha cichory, 30 t/ha	25	5	80
1 ha cabbage, 70 t/ha	80	40	170
Total output over 22 ha by sale of products	1,185	270	1,050
Total output/ha by sale of products	54	12	48
Inputs			
0.5 ton concentrates	15	3	8
2.1 tons roughage (natural areas)	42	6	45
1.3 tons straw (natural areas)	13	2	4
Wet and dry deposition (air pollution)	35	1	4
Biological nitrogen fixation	80	-	-
Total input/ha	185	12	61
Natural losses* + mutations in soil reserves/ha (input/ha - output/ha)	131	0	13

* Nitrogen losses = NH_3 - volatilization + NO_3 - denitrification + NO_3 - leaching; NO_3 - leaching = ± 10 kg/ha/year;
K losses = K leaching = ± 20 kg/ha/year.

Nitrogen availability was clearly the main limiting factor for production on the organic farm, as evidenced by yield comparisons between experimental plots in the pasture with and without clovers (Van der Meer and Baan Hofman, 1988). From these results, it has been concluded that biological nitrogen fixation was the main source of nitrogen input in the organic system (Table 3). This table also shows that a deficit on the nutrient balance of phosphorus and potassium caused by sale of products was compensated for by purchase of feed. Although this deficit existed from 1979 untill 1986, the phosphorus and potassium status of the soil is still sufficient, according to conventional standards.

Table 4. Chemical control in the conventional and integrated systems 1985-1987.

	Average number of treatments per field		Input of active ingredients (kg/ha)	
	Conventional	Integrated	Conventional	Integrated
Herbicides	2.2	1.1	4.5	1.7
Fungicides	4.2	2.2	5.0	2.7
Insecticides	1.5	0.3	0.6	0.1
Growth regulators	0.3	0.0	0.3	0.1
Subtotal	8.2	3.6	10.4	4.6
Nematicides*	0.3	0.0	42.7	0.0
Total	8.5	3.6	53.1	4.6

* Soil fumigation against potato cyst eelworms.

On the conventional farm, 8.5 pesticide treatments per field were applied; only 3.6 were applied per field on the integrated farm (Table 4). If the use of chemical means per year are expressed in kilograms per hectare active ingredient, differences are still greater, that is, 10.4 versus 4.6 and even 53.1 versus 4.6 if routine fumigation of the soil against potato cyst eelworm on the conventional farm is included. When soil fumigation was introduced on the conventional reference farm, as most farmers did at the time, we decided to grow eelworm-resistant potato varieties on the integrated farm.

Experimental introduction of integrated agriculture

From the experimental results, we have concluded that drastic reduction of the usage of fertilizers and pesticides by means of integrated farm management is attractive from an environmental point of view. The resulting cost reductions also may offer sufficient compensation for lower yields and may bring higher profits. As increasing cost of production, and especially decreasing prices of agriculture products, put profits under pressure, it becomes attractive to convert to integrated management (Vereijken, 1989b). Considering the saturation of markets and growing restrictions by environmental legislation, research on integrated farming should be extended by experimental introduction of the systems into practice. This latter would imply the testing of the prototype-system developed at Nagele by experienced and commercial arable farmers to attain technically and economically feasible farming scenarios. Undoubtedly, this will also lead to the improvement and broadening of the current integrated cropping programs, promoted by the wide variety of practices in attitude and skill of farmers, nature and size of holdings, soil types, crop rotations, and other factors. Finally, a general strategy for the development and introduction of integrated farming systems is presented (Table 5).

Tabel 5. Strategy for the development of integrated arable farming systems and their introduction in practice.

1. Research institutes develop and test the components for integrated farming systems:
   - varieties with broad resistance and good production.
   - biological, physical and chemical methods of crop protection
   - methods for the maintenance of soil fertility.
   - efficient cropping systems with emphasis on quality.
   - equipment, machines and buildings for a technically optimum management.
   - ways of investment with maximum returns of soil, labor and capital.

2. Experimental stations coordinate the composition and testing of experimental systems on Regional Experimental Farms:
   - experimental farms on representative locations in specific growing areas. For example in the Netherlands: Nagele in the central clay district (1979), Veendam in the peaty sand district (1986) and Vreedepeel in the light sand district (1988).

3. Research and extension introduce and test the experimental systems on a small scale:
   - regional formation of pioneer groups of farmers for planned conversion from conventional to integrated farming (Dutch central clay district 1990).
   - technical, economic and environmental progress has to be monitored and evaluated.
   - Major input/output relations have to be optimized and generally usable cropping and farming scenarios have to be developed.

4. Extension and education introduce integrated production systems on a large scale:
   - manuals and courses for extension specialists/and teachers.
   - adaptation of subject matter in agricultural schools.
   - courses and study groups for farmers.
   - appropriate cropping manuals and view-data.

Perspectives on organic farming

The net output of the organic mixed farm has increased steadily since 1985 when low-profit fodder crops were replaced by high-profit vegetables and milk production was raised to a higher level through supplementary purchase of concentrates. Consequently, an acceptable income can be expected in the next few years. To achieve this, it is important that a 50-percent (milk, meat) to a 100-percent (grain, vegetables) higher price level be obtained for the organic products compared to the conventional market to make up for the higher investments in capital and labor. This need of high premiums, however, appears to be too high a treshold for the majority of farmers and consumers up untill now.

This does not mean that organic farming is doomed to play a marginal role. Several developments are occurring that offer new opportunities to a more radical organic approach (Vereijken, 1989b). In areas with sensitive ecological characteristics and also in water collection areas, organic farming may play an important role because of its minimum introduction of nutrients and its rejection of chemical pest control measures. Therefore, organic farming in these areas deserves financial support from public funds. Finally, an increasing demand on the European market for organic products is occurring, inspired by growing concerns for mankind and the environment and for the well being of animals. Sooner or later this may lead to a breakthrough of organic farming into the conventional practices of farm production, trade, and consumption.

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The Third Way, a research project in ecologically orientated farming systems in Switzerland

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ABSTRACT

In contrast to a "first way" (high input) and a "second way" (reductionist, directed to single problems), the "Third Way" should be a global, holistic approach with emphasis on ecological requirements. Economic requirements have to be reconciled with the need for safeguarding man and his environment as well as nature for its own sake.

The project includes comparisons between "integrated", "conventional" and farming "without pesticides". The general aims of the emphasized integrated farming system are: 1) maintenance and promotion of natural regulation factors, 2) reduction of external inputs to protect the environment and save costs, 3) maintenance of income and employment of farmers.

The integrated cropping systems are based on detailed guidelines for the farmer (Tables 1 - 3). These are flexible in the sense that, supplementary to a guaranteed minimum, the farmer can choose between different recommended measures and the farming system is adapted every year to new knowledge (including the farmer's experience).

Three commercial farms provide on-farm research and serve as integrated pilot-farms: (A), a mixed farm with 19 LU-cows, 16 ha, (B), an arable farm with 170 pigs, 20 ha and (C), a mixed farm with 13 LU-cows, 10 ha (subsidiary earnings of the farmer).

For economic analysis, the integrated pilot-farms (A) and (B) have been compared with conventional farms of similar structure (1981 - 1987, Tables 5 - 8). The integrated farms had a lower average yield of maize (-6 %), milk (-6 %), and the same yields of sugar-beet and wheat. The direct margins (gross margins plus costs of hired machines and labour) were lower in maize (-7 %), but higher in wheat (+7 %), sugar-beet (+9 %), and milk (+ 32 %, due to less costs for supplementary feed).

More detailed analyses are also made on the three integrated pilot-farms themselves: the defined integrated farming system is applied on the farm as a whole, but reference strips are supplemented with conventional farming and without pesticides.

The average number of chemical treatments per field and per year (mean of all crops on the 3 farms) was respectively 4.4 in conventional and 1.2 in "integrated".

A number of bioindicators are being investigated: the density of earthworms and cellulose decomposition rate were significantly higher in low-input farming systems.

The influence of weeds and of marginal biotopes on pests and on beneficial organisms is described, showing a positive effect on beneficials.

KEY WORDS: farming systems research; integrated farming; ecological farming; ecosystems; agricultural economics; cultural measures; bioindicators; ecological compensation; beneficials; side-effects.

1. INTRODUCTION

Substantial economic protection is likely only partly to stop Swiss agriculture from becoming intensified. In addition, the creation of the EEC open market in 1992, and GATT negotiations, may compel politicians to change from a protective to a more market-orientated agricultural policy. Countries with a high standard of living and high production costs, such as Switzerland, should not produce the largest amount of food as cheaply as possible (cf. CARTER & NUCKTON, 1988). Production schemes come first which are ecologically and toxicologically safe. Swiss consumers may be prepared to pay more for home-produced food in the future, if it is of high quality and ecologically produced. Moreover, cost expensive Swiss agriculture cannot compete on foreign markets. Production is almost completely for the national market (with the exception of cheese) which is only 60 % self-sufficient.

At national and international levels intensification was considered to be the answer to inadequate price compensation for the high increases in costs over recent years. As a result, a complex of problems arises:

a) overproduction and increasing dependency on non-renewable resources,
b) pollution of the environment and interference with nature and the landscape,
c) residues in food and consumers' mistrust of food quality,
d) reduction of both diversity and density of beneficial organisms, increases in resistant pests, diseases and weeds.

To solve these problems, we distinguish three possibilities:

1) To continue with a high input strategy, but with modifications and/or use of alternative or supplementary inputs.
2) To analyse the problems in a reductionist way, so as to solve problems solely, e.g. to eradicate particular pests.
3) The third alternative is a holistic approach with emphasis on ecological requirements, attempting to develop concepts for a long-term, sustainable agriculture. It is agro-ecosystem-orientated, promoting the system's capacity for self-regulation. The economic requirements (which change quite often) have to be reconciled with the need for safeguarding man, his environment and nature for its own sake. For this approach it is vital to submit the farming system as a whole to these goals. It has to be dynamic and flexible, adapted continuously as new knowledge is acquired.

The third alternative is in agreement with "integrated farming" in the sense of STEINER *et al.* (1977, 1986) and VEREIJKEN *et al.* (1986). In contrast, other definitions of "integrated farming" (e.g. KELLER, 1985; HEITEFUSS, 1987) omit the very important priority to preserve and activate natural regulation factors.

In Switzerland considerable efforts on integrated pest management have been done, especially in fruit cultivation and in viticulture, but less so in arable crops (BOLLER *et al.* 1986). Crop systems research has progressed in fruit and viticulture (e.g. BAGGIOLINI *et al.*, 1973; BOLLER & REMUND, 1986). However, systems research of arable farming on a farm scale has been missing.

For arable and mixed farming systems a project called "The Third Way", corresponding to the third alternative described above, was started in 1983 (preliminary data since 1981) at the Swiss Technical College of Agriculture (HÄNI, 1983). The concept and the first results of this project are now described.

2. PRESENTATION OF THE THIRD WAY PROJECT

2.1. OBJECTIVES AND TECHNIQUES OF FARM MANAGEMENT

Within the "Third Way" project, commercial farms provide on-farm research and serve as demonstration-farms ("pilot-farms"). The objective is to develop integrated arable and mixed farming and to compare them to some extent with conventional and organic farming. - The integrated farming systems have to meet minimal requirements, based on results of monofactorial research with favourable ecological and economic effects; farming systems are combinations of compatible components. In addition to Tables 1 and 2 the restrictions published by HÄNI, 1987; NIKLAUS et al., 1989 (variant "goal") and HOFER, 1989, have to be fulfilled.
Farmers are stimulated by flexible requirements to make their own experiments and observations. Their knowledge and experience are taken into account for evolving the specific farming procedures. Since ecological insights especially are lacking, the "Third Way" project includes appropriate ecological research.
The general aims for applied integrated farming are:

a) Maintenance and promotion of natural regulation factors: e.g. disease suppression by crop rotation, resistant/mixed cultivars, careful soil preparation, favouring antagonists by supplying shelter and food.
b) Reduction of external inputs (fertilizers, pesticides, energy) to protect the environment and save costs. Selective pesticides, if possible at reduced dosages, may only be used as a last resort and then in a supervised way. The pesticides are selected on ecological and toxicological criteria (Table 1). Maximum yield aspirations are restricted (in good cereal production areas e.g. 70 - 75 dt wheat/ha at the moment).
c) Income, employment and the social standard of farmers must be maintained and, if possible, improved. Since increasing yield is counter-productive, cost reduction is a major objective. Another possibility is to establish contracts between farmers and the trade, based on special prices.

2.2. EXPERIMENTAL SITES

The following pilot-farms are included in the "Third Way" Project:
Farm (A), results since 1981:
This is a **mixed farm** of the average size for Switzerland (16 ha), located at **Ipsach**, close to the lake of Bienne, 450 m above sea level, and operated by H. Gassner. It includes a dairy unit of 19 cows. The mean precipitation per year is 850 mm. Climate is comparatively mild (close to a lake). "Winter feeding" (without fresh fod- der) lasts 140 days. Annual mean temperature is 8,7 °C (April - October: 13,8 °C). The soil ranges from a sandy loam to a loamy silt.
Farm (B), results since 1985:
It is also at **Ipsach** and belongs to M. Käser, who was convinced by the results of his neighbour Gassner. This is an **arable farm** of 20 ha, 430 m above sea level. Livestock is limited to 170 fattening pigs. The soil is sandy loam to silt-loam (lake-deposit on peat and chalk).

Farm (C), results since 1988:
It is run by the tenant farmer, R. Krähenbühl, and is at **Schlosswil,** 750 m above sea level. This **mixed farm** of 10 ha, including a dairy herd of 13 large animal units, has been chosen for its small size (below the economic viability limit, the farmer needs subsidiary earnings). The mean precipitation per year is 1300 mm. The climate is harsh, the winters are usually hard, and "winter feeding" lasts 180 days. Annual mean temperature is 7 °C (April - October: 11 °C). The soil is loam.

For factorial and more complex ecological experiments other sites are also used.

2.3. ORGANISATIONAL STRUCTURE

The "Third Way" project, originally operated on a voluntary basis, has been accepted as an official project by the administration of the Swiss Technical College of Agriculture (STCA) since 1988. Now two members of staff from STCA are involved (up to about 20 % of their time) and some work is done with students. Cooperation exists at different levels with several institutes, universities (Berne and ETH Zürich), agronomy research stations (Reckenholz-Zürich, Nyon-Changins, Liebefeld-Berne), agricultural schools, and extension services are involved.
From 1989 the farms involved make contracts with the "Swiss union of agricultural cooperatives" within a project called "Agri Natura" (HOFER, 1989). This includes extension services with, for example, epidemic prediction, soil analysis and information and training. Animal products and in future probably also plant products with the "Agri Natura" label receive higher prices. In order to qualify for this label, all products of the farm have to be produced within the restrictions and to be accepted every year according to controls (registration of measures, farm visits, analysis). For the future, additional public contributions for these production schemes are to be examined.

3. EVALUATIVE RESEARCH

3.1. EXPERIMENTAL LAYOUT

The defined integrated farming system (Tables 1 and 2) is applied to the whole of each pilot-farm. Additional reference plots are included for conventional farming and farming without pesticides (Fig. 1, Table 3). The plots are kept in the same position during the whole crop rotation. In Table 4 are listed the crop rotations. Fig. 2 shows how catch crops are inserted on farm (A).

3.2. DESIGN AND MANAGEMENT

The farm manager is trained in the integrated approach and makes his decisions after discussions with the project leader, who coordinates information coming from research, extension and practice.
The experimental variables for the high input, conventional system and that without any pesticides are defined by the project leader. The guidelines for the conventional system are those in use in that region (Table 3).

Table 1 General requirements for the applied integrated farming system

1) Areas for ecological compensation
   - Hedgerows and their borders and marginal biotopes (unmanured rough meadows, borders of fields, slopes, etc.) should cover 3 - 7 % of the farm land.
   - A part of cultivated meadows should be extensive (low input of fertilizer).

2) Soil tillage
   - Only in dry soil. Plough only if necessary and usually in spring, except heavy soils with high content of clay.
   - For soil preparation, double-tyres or equivalent to reduce ground pressure.

3) Rotation
   - Suppression of diseases, pests and weeds and reduction of N-leaching.
   - ≥ 4 different crops/rotation
   - ≤ 50 % cereals; ≤ 33 % maize; ≤ 33 % potatoes; ≤ 25 % sugar-beet; ≤ 50 % "hoed crops" (potato, sugar-beet, rape, pea, bean).
   - mixed farms: ≥ 2 years of meadows/10 years
   - overwintering crops or soil cover

4) Manuring
   - Equalized balance of plant nutrients on the whole farm. Supplies of P, K, Mg, Ca, N cf. Tables 2 and 3.
   - Green manure wherever appropriate (also as soil cover).
   - Stable manure: adapted allocation based on content of manure.
   - Arable farms without cattle: straw, leaves of sugar-beet etc. left on fields.

5) Plant Protection
   - Priority is on natural limiting factors: rotation, resistant/mixed cultivars, no chemicals to reinstate meadows, reduced nitrogen supply, maintenance and stimulation of antagonists.
   - Use of control thresholds and epidemic prediction systems. If pesticides are unavoidable, the choice is based on toxicity to man and other non-target species, especially beneficials (BOLLER *et al.*, 1989), resistance mechanisms, persistence and mobility. If possible use at reduced dosage and restrict to seed row treatment.

6) Animal husbandry
   - ≤ 2 "large animal manure units"/ha (LMU/ha)[1] for open arable land; ≤ 2,5 LMU/ha for meadows.
   - ≥ 80 % fodder from own farm (exchange possible, e.g. barley for wheat).
   - Fodder without non-essential substances (no growth stimulators).
   - Prescriptions on stable area per animal and on type of stable (MURRI & SCHNEIDER, 1989)

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[1] Equivalent to manure from a 600 kg cow

Table 2 Crop-specific requirements for integrated farming in wheat (similar for other crops, cf. HÄNI 1987)

	Obligatory	Recommended	Allowed	Disallowed
Fertilization	• N: first application 100 kg-N_{min}, but < 60 kg. Later applications < 60 kg (+ missing from 1. application)	• N_{min} • Quick-test • Small control plots without N (to control subsequent delivery)	• Use of sewage sludge	• N fertilization after heading (DC 49)
Control of pests and diseases	• Several cultivars or mixed cultivars[1] • < 40 % wheat • Sowing date later than 5. October (higher regions 1. October) • Use of pesticides based on criteria in Table 1	• Sowing date later than 15. October (higher regions 10. October) • On field borders (3 m) no pesticides (except when problematic weeds), reduced fertilization	• Pesticides according to EPIPRE (except fungicicides against eyespot) • Pesticides according to control thresholds (relatively high level of thresholds) • Seed-treatment • ≤ 1 fungicide spraying per year	• Growth regulators (e.g. CCC) • Wheat after barley or wheat • Highly susceptible cultivars • Fungicides against eyespot
Control of weeds	• Mechanical weed control • Immediately after harvest mechanical control of germinating wheat • Wheat followed by catch crop or green manuring	• Spot-or single plant treatment of perennial weeds • Mechanical control of <u>Agropyron repens</u> after harvest	• Post emergence herbicide according to control thresholds	• Pre emergence herbicides

[1] selected for resistance against pathogens and lodging and secondly for yield capacity

Table 3 Major differences between the applied farming systems.

	Integrated	Conventional	Without pesticides
Fertilization			
- P, K	• based on soil analysis	• ditto	• ditto (if possible organic and from own farm)
	• input ≤ uptake	• input equal to uptake	
- N	• based on N_{min} and other methods	• ditto	• "
	• "suboptimal"	• "optimal"	• "suboptimal"
Control of pests and diseases			
- resistant varieties	• as much as possible	• only if high-yielding[1]	• as much as possible
- mixtures of different varieties	• strongly recommended (wheat)	• no	• the same as in "integrated"
- biological	• as much as possible	• if standard	• as much as possible
- chemical	• as last resort	• if standard	• no (except treated seed)
Control of weeds			
- mechanical	• always (arable crops)	• seldom	• always
- chemical	• as last resort	• normal procedure	• no

[1] For practical reasons in on-farm comparisons often the same variety as for "Integrated".

Table 4 Crop rotations of the three pilot-farms (catch crops and undersowing cf. Fig. 2)

Year	Farm (A)	Farm (B)	Farm (C)
1	W.wheat	W.wheat	W.wheat/Triticale
2	Maize/Sugar-beet	Rape[2]	Potato/Maize
3	W.wheat (Rye)	Maize	Oats
4	Potato/Rape[2]	W.wheat	W.barley
5	W.wheat	Sugar-beet	Meadow
6	Meadow	Oats	Meadow
7	Meadow	-	Meadow
8	Meadow	-	Meadow

[2] with 2 % bird rape (for attraction of pests, BÜCHI et al., 1987)

Fig. 1: Example of an experimental field within a commercial farm.
☆: Counts of weeds (1 m^2 each); counts of diseases, pests elsewhere; ▫ : Samples for yield and yield components (paired values); ❁ : Earthworms (1/4 m^2 each), nematodes; ✱ : Cellulose degradation (3 filter papers each).

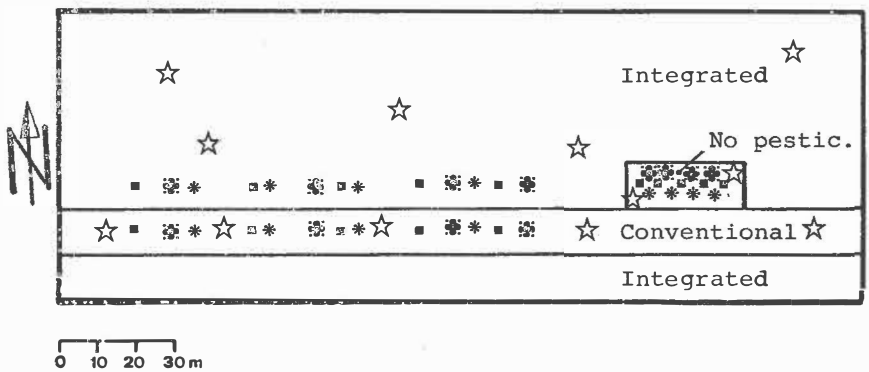
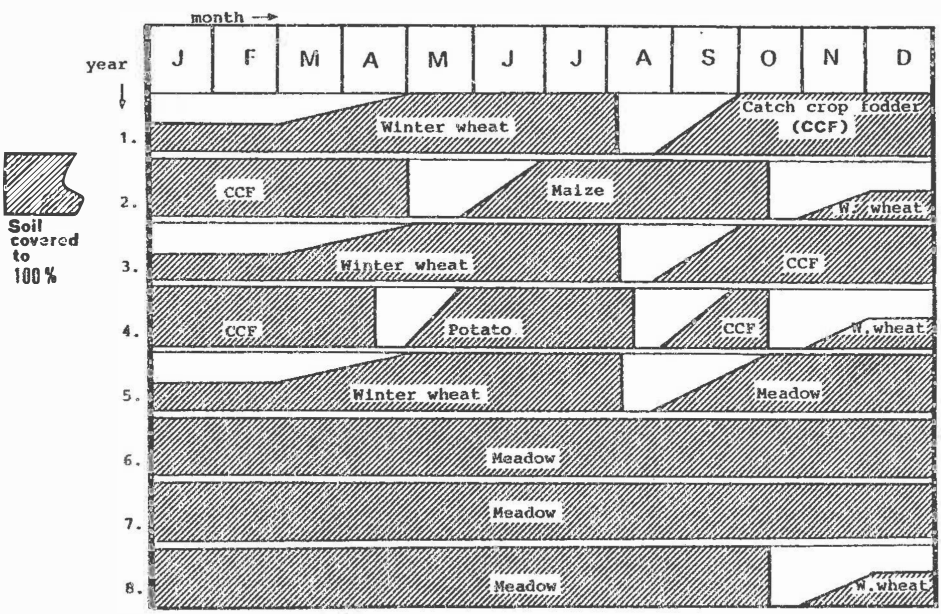


Fig. 2: Crop rotation on farm (A). Maize with undersowing. One of the objectives is to minimize breaks in soil cover.



3.3. ANALYSIS AND SYNTHESIS

The economic results from the integrated pilot-farms are compared with those from conventional farms. For more detailed analyses, comparisons are made also on the pilot-farm itself (Fig. 1). Diseases, weeds and pests are evaluated during the vegetation period. Yields and yield components are determined in 5 replicates and also for the entire plot. For ecological analysis several bioindicators are investigated: earthworms (4 replicates at 1/4 m^2 with modified formalin method, cf. RAW, 1959), nematodes, cellulose degradation and to some extent beneficial insects (weekly exposure of pitfall traps, 10 cm diameter; insect nets, 50 cm diameter and 1 mm mesh, etc.). Every year we try to make a synthesis of our own results, the farmer's observations and experience, together with outside knowledge to improve the integrated farming system.

4. TRANSFER OF KNOWLEDGE

To support the introduction of integrated and environmentally sympathetic farming in general practice a book has been published (HÄNI et al. 1987/88) together with articles in popular periodicals.
Moreover, we organize excursions for farmers' groups and for consumers (in cooperation with a newspaper). A TV programme on farm (A) was made.
In different Cantons (counties) colleagues have begun to introduce and recommend integrated arable farming with other farmer groups, and there is a good information-transfer. To some extent, colleagues have begun also to set up pilot-farms (in Canton Fribourg, Canton St. Gallen), and there are already plans to establish a network of pilot-farms throughout Switzerland.

5. RESULTS

5.1. ECONOMIC AND AGROTECHNICAL PARAMETERS

The economic results from farms (A) and (B), compared with conventional farms, are listed in Tables 5 - 8. Latest comparisons (1988) between integrated, conventional, and plots without pesticides on the farms (A), (B) and (C) themselves are described in Table 9. It should be pointed out that the financial loss in integrated wheat production was greatest in the year represented (1988). Against this, in 1986, with other weather conditions, the direct margin of wheat was better in integrated than in conventional (+ 5 %). Table 10 shows the use of chemical products in integrated and conventional farming (standard seed treatment is not included).

Table 5 **Overall economic results (SFr.) of the integrated mixed farm (A), a mixed farm with 16 ha, compared with the average of 310 conventional farms of similar structure (av. 17,3 ha), 1981 - 1984.**

	Integrated farm (A)	Conventional (Av.)
Direct margin/ha[1]	8890	7840
Direct margin/man hour	35	31
Agricultural income[2]/ha	5750	3790
Agricultural income[2]/ man hour	23	15

Table 6 **Overall economic results (SFr.) of the integrated arable farm (B), an arable farm with 20 ha, compared with the average of 9 conventional farms of similar structure (av. 23,2 ha), 1985 - 1986.**

	Integrated farm (B)	Conventional (Av.)
Financial yield/ha	13600	15400
Direct costs/ha[1]	5400	6380
Direct margin/ha	8200	9020
Direct margin/man hour	36	35
Agricultural income[2]/ha	4810	4060
Agricultural income[2]/ man hour	21	16

[1] Financial yield minus direct costs comprising seed, fertilizer, pesticides, insurance (costs for hired machines and labour not included)

[2] Direct margin minus external non allocatable costs comprising building costs, external labour costs, etc.

Table 7 Physical yields (dt/ha;dt/cow) and financial results (SFr/ha;SFr./cow) of winter wheat, sugar-beet, potato, and dairy cattle on the integrated mixed farm (A) (Int.), compared with the average of 18 conventional farms of similar structure (Conv.), 1981 - 1987.

	Winter wheat		Sugar-beet		Potato		Milk yield	
	Int.(A)	Conv.	Int.(A)	Conv.	Int.(A)	Conv.	Int.(A)	Conv.
• Physical yield	56	54	610	610	330	370	49	52
• Financial yield	5690	5600	10330	10250	12800[2]	10870	4350	3790
• Fertilizer	230	390	230	590	340	530	(90	570)[3]
• Pesticides	130	210	210	570	200	420	-	-
• Total direct costs	950	1220	790	1330	2270	3210	280	770
• Direct margin[1]	4740	4380	9540	8920	10530	7660	4060	3070

Table 8 Physical yields (dt/ha) and financial results (SFr./ha) of winter wheat, sugar-beet and maize on the integrated arable farm (B), compared with the average of 9 conventional farms of similar structure (Conv.), 1985 - 1986.

	Winter wheat		Sugar-beet		Maize (Grain)	
	Int.(B)	Conv.	Int.(B)	Conv.	Int.(B)	Conv.
• Physical yield	54	55	640	630	93	99
• Financial yield	5770	5900	13110	11650	6650	7080
• Fertilizer	230	420	450	490	350	420
• Pesticides	90	250	200	490	60	140
• Total direct costs	1020	1400	1070	1430	720	890
• Direct margin[1]	4750	4510	12040	10210	5920	6190

[1] Cf. Table 6 [2] A part is marketed directly [3] Costs of supplementary feed

Table 9 Comparisons between "integrated", "conventional" and plots "without pesticides" on the pilot-farms themselves. Physical yields (dt/ha) and financial results (sFr./ha) of winter wheat, 1988.

	Integrated				**Conventional**				**Without pesticides**			
Farm:	(A)	(B)	(C)	**Mean**	(A)	(B)	(C)	**Mean**	(A)	(B)	(C)	**Mean**
• Physical yield	66	73	54	**64**	72	79	64	**72**	55	66	54	**58**
• Financial yield	6640	7220	6250	**6700**	7240	7830	7340	**7470**	5530	6580	6250	**6120**
• Fertilizer, sFr.	80	360	290	**240**	80	360	380	**270**	80	360	290	**240**
• Pesticides, sFr.	100	40	0	**50**	350	350	290	**330**	0	0	0	**0**
• Total direct costs	780	1080	1170[2]	**1010**	1060	1410	1610[2]	**1360**	650	1030	1170[2]	**950**
• Direct margin[1]	5860	6140	5080	**5690**	6180	6420	5730	**6110**	4880	5550	5080	**5170**
• Hired machines and labour	350	260	420	**340**	350	260	400	**340**	350	260	420	**340**
• Gross margin	5510	5880	4660	**5350**	5830	6160	5330	**5770**	4530	5290	4660	**4830**

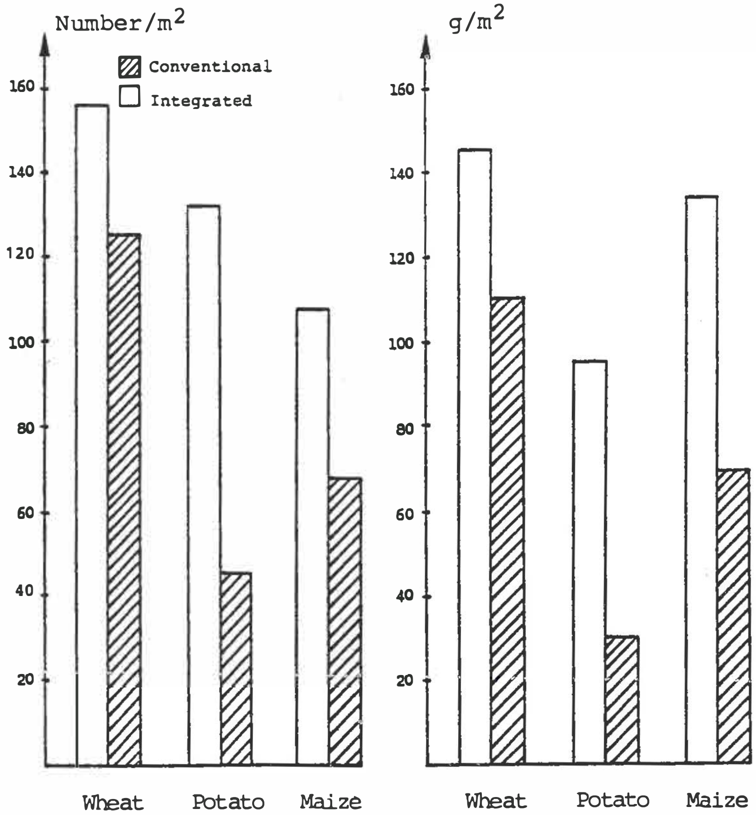
[1] Cf. Table 6 [2] Including drying of kernels

Table 10 Numbers of chemical treatments in integrated (Int.) and conventional (Conv.) farming per field and per year, 1987/1988. Averages of farms (A), (B) and (C).

	Maize		**Wheat**		**Potato**		**Sugar-beet**		**Mean**	
	Int.	Conv.	Int.	Conv.	Int.	Conv.	Int.	Conv.	Int.	Conv.
• Herbicides[3]	0.3	1	0.6	1.3	0.3	1.8	0.5	1.3	**0.4**	**1.4**
• Fungicides	0	0	0.3	2	3	6	0	0.5	**0.8**	**2.1**
• Stem shortener	-	-	0	0.	-	-	-	-	0	0.2
• Insecticides/ Nematicides	0	1	0	0,9	0	0	0	1	0	**0.7**
T O T A L	0.3	2	0.9	5.1	3.3	7.8	0.5	2.8	**1.2**	**4.4**

[3] Including defoliation sprays; strip-treatment in seed row counted as 0.3

Fig. 3: Number and weight of earthworms (*Lumbricidae*) in integrated and in conventional farming (for each crop 2 trials with 4 replicates)



5.2. ECOLOGICAL PARAMETERS

Several bioindicators are being investigated. The population density of *Lumbricidae* is significantly ($P < 0,01$) higher in integrated than in conventional farming (Fig.3). Factorial experiments have shown the negative influence of repeated cultivation of the same crop, of repeated ploughing and of some pesticides (Benzimidazoles, Carbofuran) on *Lumbricidae*. Nematodes are also being routinely investigated, but so far without interpretable differences among the farming systems. The first results have shown significantly higher degradation of cellulose in integrated than in conventional plots on farm (A) in 1988.

Fig. 4: 5 species of Syrphinae, with Sphaerophoria scripta the most frequent, in 2 neighbouring fields of w.wheat. Significant differences at every date (WILCOXON Rank Sum Test). Cf.Fig. 5.

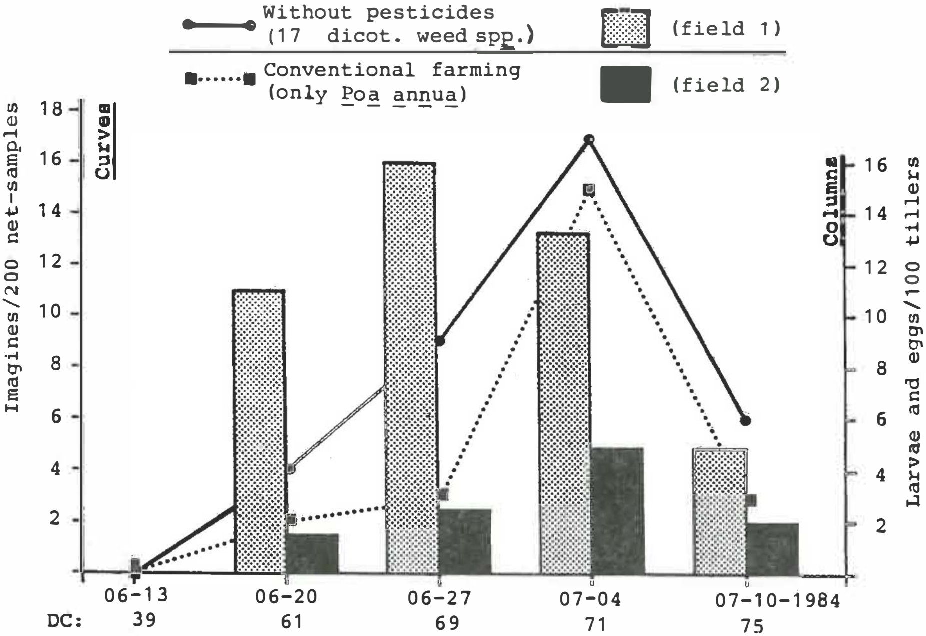
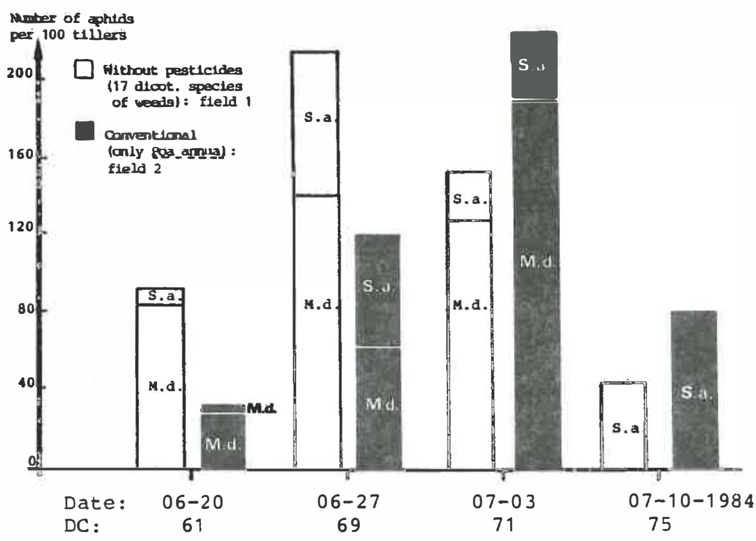


Fig. 5: Aphids, Sitobion avenae (S.a.) and Metopolophium dirhodum (M.d.), in 2 neighbouring fields of w.wheat. Significant differences at every date. Cf. Fig. 4.



We have paid special attention to the influence of tolerated weeds, marginal biotopes and mixed cultivars on pests and beneficials. - Weed flora in wheat fields promoted different beneficial organisms like Syrphidae (Fig. 4), Staphylinidae, some Carabidae species, parasitic Hymenoptera, spiders and Entomophthoraceae. Aphids occured earlier in these fields (Fig. 5, cf. corresponding development of hoverflies in Fig. 4), but due to the natural decline of populations, control thresholds were never reached. - The influence of hedges with unmanured herbaceous border was quite similar; in adjacent wheat fields pests such as aphids, Oulema spp. (mainly O. melanopa), Chlorops pumilionis and especially beneficials like Staphylinidae, some Carabidae species, Syrphidae, Chrysopidae and parasitic Hymenoptera appeared earlier and/or at a higher density. - Flowering plants around wheat fields in particular were attractive to beneficials (Syrphidae, parasitic Hymenoptera). These results on the influence of marginal biotopes and "weeds" are in good agreement with other recently published data (reviewed by KNAUER & SCHROEDER, 1988; STECHMANN & ZWOELFER, 1988; WELLING et al., 1988). - The mixture of rape seed (Brassica napus var. napus) with 2 % bird rape (B. rapa var. silvestris) reduced significantly Meligethes aeneus, Ceuthorhynchus napi and C. quadridens on cropped oilseed-rape (cf. BÜCHI et al., 1987).

6. DISCUSSION

In our "low budget approach" only the integrated farming system could be fully laid out. For conventional farming a part of the fields were treated as reference, using more pesticides and fertilizer (Table 3). This conventional reference part could benefit from some basic "integrated" measures, which are applied for the entire farm (crop rotation, resistant cultivars etc.). For this reason the results of Table 9 are too pessimistic for integrated farming.

In order to include also conventional systems in the broad sense, we compared economic results of the integrated farms with conventional farms of similar structure (Tables 5 - 8).

It can be concluded, that the results of the applied integrated farming system are very promising. The farms involved have become quite attractive as pilot-farms for farmers' groups, extension services etc. We will continue the project as described. We hope especially that together with others we can contribute to environmentally safe, sustainable agriculture.

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Farming Systems Research on arable crops in the U.K.

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INTRODUCTION

Within the UK, work on Farming Systems has not been done in ways which enable comparisons to be made with projects in other parts of Europe. Most projects relevant to Integrated Farming Systems have been relatively short-term and with specific objectives in crop production or crop protection. Examples are: the Ministry of Agriculture Boxworth Project concerned principally with the environmental effects of pesticides in whole fields within a cereal monoculture; the Cereal and Gamebirds project of the Game Conservancy which explores opportunities to increase gamebirds by reducing pesticide use on crop margins; and research on the development of new techniques for pest control by the Agriculture and Food Research Council and other organisations in the UK.

Now that Long Ashton Research Station has been given special responsibility to research aspects of low input farming, and the Ministry of Agriculture plans to include crop rotation and other husbandry practices in projects to follow the Boxworth work, there are opportunities for AFRC/MAFF collaboration in developing UK research in comparable ways to that in other parts of Europe, such that farmers in different member states can benefit from research findings and experience in others.

Motivation and Objectives

(i) to reduce inputs in arable crop production, to save energy and costs.

(ii) to reduce the undesireable side effects of certain agronomic practices on environment, nature and landscape, and ensure that future strategies for crop protection are compatible with environment protection.

SUMMARY OF RESEARCH IN UK ON RELEVANT COMPONENTS

There is substantial research in progress in the UK (MAFF, IACR and other organisations) into aspects of agriculture that are directly relevant to the design of integrated farming systems. These are too numerous to list individually, but some of the major areas covered are shown below (Table 1).

Table 1. Research in UK relevant to Integrated Farming Systems.

1. Soil chemistry	balance of nitrogen and other nutrients in soils of various types, in relation to agricultural practice, including use of organic manures.
2. Straw disposal	studies comparing methods and effects of straw incorporation.
3. Beneficial invertebrates	impact of predators and parasites on pests; effect of chemical control on beneficial species; development of IPM programmes.
4. Plant breeding	production of disease resistant crop cultivars and development of strategies for enhancing resistance (varietal mixtures).
5. Treatment thresholds	refinement of practical methods for establishing thresholds for economic losses due to pests, weeds and diseases.
6. Control technology	improvement of chemical and non-chemical pest control, including specific targeting of pesticides (seed treatments, spray technology).
7. Farm forestry	research into the incorporation of trees into cropping programmes (bulk biomass production in short-term rotations).
8. Fallowing	in relation to set-aside practices, experiments are in progress into the agronomic and ecological effects of leaving land fallow.
9. Field margin management	alternative approaches to minimising habitat damage and loss of reservoirs for beneficial species while avoiding pest problems and protecting yields.
10. Yield and economics	all aspects of the growth and performance of crops in relation to management and environmental factors.

<u>AFRC, Institute of Arable Crops Research (IACR)</u>

<u>Long Ashton Research Station (LARS): Rothamsted Experimental Station (RES)</u>

IACR research is concentrated on the identification of factors limiting the adoption of Integrated Farming Systems and on developing ways of reducing their significance.

Ways of avoiding or reducing the use of nitrogen, and broad-spectrum pesticides, especially on cereals, are being investigated in a series of field experiments.

Table 2. Research in AFRC relevant to Integrated Farming Systems.

Activity	Researchers and Institute
1. Optimal use of interactions between agrochemical and fertiliser inputs.	V.W.L. Jordan & J.A. Hutcheon (LARS)
2. Population dynamics of weeds and competition studies.	G.W. Cussans, B.J. Wilson & K.J. Wright (LARS)
3. Manipulation of beneficial fauna.	B.D. Smith, D.A. Kendall & D.M. Glen (LARS)
4. Disease forecasting.*	D.J. Royle & M.W. Shaw (LARS)
5. Straw incorporation, cultivation and pest control.*	B.D. Smith, D.A. Kendall, D.M. Glen, V.W.L. Jordan, G.W. Cussans & S.R. Moss (LARS); R.D. Prew (RES)
6. Set-Aside.*	R.D. Prew (RES)
7. Increasing the efficiency of nitrogen.*	A.E. Johnston & D.S. Powlson (RES)
8. Variety/species mixtures.	M.S. Wolfe** (Plant Breeding Institute, Cambridge)

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*Work on these aspects is also being carried out by the Agricultural Development and Advisory Service (ADAS).

1. Interactions between agrochemical and fertiliser inputs

The effects and interactions of crop husbandry practices on crop growth, structure, disease and quality yield are being qualified and quantified, to provide scientifically sound justification for their inclusion in arable growing systems in order to integrate their benefits for optimal use and efficient crop production. Studies in winter barley have provided options for reduced fertiliser and fungicide inputs, and demonstrated that a single fungicide application made to crops where the main nitrogen top dressing was deferred until April (compared with the traditional UK nitrogen top dressings in mid-March and a 2 - 3 fungicide spray requirement) was sufficient to optimise quality yield, cost- effectively. Similar studies in winter wheat have demonstrated the profound effects of nitrogen forms and timing on disease, and identified biological properties of fungicides that underlie their action against the range of diseases that affect wheat. Integration of these properties has suggested ways by which nitrogen amounts and the frequency of fungicide sprays may be reduced, and provided options to meet the requirements in developing integrated farming systems.

2. Population dynamics of weeds and competition studies

The general principles of crop response to increasing weed density and factors influencing the effects of weed competition have been established. Indices of relative competition ability of a range of weed species have been prepared. Seed production is measured and viability, dormancy and longevity studied. Future plans concentrate on variability of weed growth and development. Soil nutrients and moisture will be varied to assess the impact of weed populations and their competition with crops. The emphasis has been on short-term (up to three years) studies on specific aspects of weed ecology, including soil tillage. These data on demography of weeds have been incorporated into a series of population models which allow simulation of a range of agricultural situations. Longer-term work has been undertaken to validate these models of long-term behaviour. This, and the problems of "scaling-up" from microplot to whole-field situations have direct relevence for an integrated farming systems approach.

Weeds present an especial problem in reduced input systems and populations are powerfully affected by many, if not most, cultural operations.

3. Manipulation of beneficial fauna

Long-term studies on the resilience of invertebrate populations and communities to habitat disturbances in farmland are in progress. In particular, the impact of straw disposal, cultivation, crop rotation, herbicide and pesticide use on pests and on the non-target invertebrate fauna, and the implications for pest and disease management (IPM). This work is integrated with similar studies on plant and weed communities in arable land. Studies are also concerned with development of suitable experimental methodology related to scale (plot size : field) and with simulation computer modelling of the spacial and temporal effects of crop agronomy and pesticides. These studies form an essential component for farming systems research.

4. Disease forecasting

New approaches to disease forecasting based on sound knowledge of the main biological and physical interactions which regulate disease development in crops are being developed. Good progress has been made towards forecasting the timing and severity of Septoria tritici, currently the most serious foliar disease of UK winter wheat, and attempts are being made to integrate control of this disease with that of other wheat pathogens. On a medium- to long-term scale forecasting warns of the broad disease risk in an area to allow strategic crop protection decisions to be made. In the short-term it offers tactical means to time control precisely according to need. It is thus likely to be an important component of both low input and integrated farming systems provided its accuracy and applicability can be relied upon in a variety of circumstances.

5. Straw incorporation

The disposal of straw by incorporation as opposed to burning results in changes in the physical, chemical and biological condition of the soil. The repercussions of these changes in terms of cultivation requirements, fertiliser and pesticide use, and on growth and yield of the crop is the subject of a co-ordinated research programme within AFRC Institutes and in conjunction with MAFF. Current research on the interactions between straw disposal and cultivation methods and pesticide use is suggesting ways of increasing the integrated control of some pests and diseases which will both reduce costs and protect wildlife.

6. Set-aside

Set-aside is being introduced in the UK to limit the production of cereals. However, it also has the potential to make a considerable contribution towards decreasing the overall level of farm inputs; by preventing pesticide and fertiliser use during the set-aside period, and by decreasing the input requirement for following crops. Work is in progress to evaluate the merits of alternative set-aside strategies and their effect on the two following cereal crops and on the environment; in particular the effect on nitrogen loss during the set-aside and in following crops. Weeds, pests other fauna and diseases are also being monitored.

7. Increasing efficiency of nitrogen

Opportunities to reduce applied nitrogen, and therefore costs, and also to reduce undesireable side effects of nitrogen are expected to come from studies on: (i) measurement and, eventually, prediction of N mineralisation in different situations (soil types; cropping histories) and of the release of N as the residues of different crops decompose in soil, particularly residues from grass or leguminous leys, on the quantities of N mineralized, the time course of N mineralization and the losses by leaching, (ii) practical ways of achieving the desired level of crop production whilst minimising N loss - compromises between what is ideal from the point of "tight" N cycling and what is agronomically sensible, for example:- (a) the extent to which early sowing of autumn crops can minimise N loss the winter, (b) the use of cover crops to achieve this if spring crops are to be grown, (c) undersowing of either cover crops or legumes may achieve sufficient autumn growth, but competition within the companion crop must be considered, (d) minimising cultivation in the autumn may minimise the autumn flush of mineralization, (e) immobilisation of N following incorporation.

8. Variety/species mixtures

Appropriate mixtures of varieties with different genes for disease resistance can limit considerably the spread of disease in a crop stand. This is applicable to many crops, both in agriculture and forestry, and to many diseases that are spread by airborne spores. Some splash-dispersed pathogens may also be restricted in this way, but little is known about the effects of mixtures on pest development. With increasing intensification of agriculture in Europe, cultivation of mixed species has often been overlooked. However, field trials show that these may have significant yield and other benefits, but little is known about their possible advantages for minimising the damage due to diseases and pests. Both of these tactics, either separately or combined, could have potential in future strategies for integrated farming systems.

MATERIALS AND METHODS

Prospect and plans for starting up large-scale IFS experiments IACR, Long Ashton Research Station

On-going component research (and future studies on Integrated Farming Systems) is done at the Institute of Arable Crops Research (IACR) Long Ashton, a state-aided Institute of the Agricultural and Food Research Council, situated in south-west England. Much of the Research Station's work concerns arable crops. Its remit is to be a national and international centre for basic and applied research on plant growth regulation, on the control of pests, diseases and weeds and on the integration of environmentally-acceptable crop protection practices into agricultural and related systems.

The Research Station is organised into three research departments: Crop Protection, Plant Sciences and Weed Research. Much research is multidisciplinary, with close collaboration and interaction between staff of the three departments, and with other organisations in the public and private sector.

Including rented adjacent land, 160 ha are under arable crop rotation; winter wheat predominates (41 ha) followed by winter barley (17 ha), grass leys (17 ha) and oilseed rape (9 ha). A range of "alternative" crops, including willows and biomass crops, field beans, sunflower, linseed, lupins and fruit trees are also grown. The area has a relatively high rainfall (875 mm/year), mild winters, an early spring and relatively cool summers, conditions ideal for crop protection research since pests, diseases and weeds are consistently prevalent. The farm has several different soils, including freely drained, well structured loams, deep fine sandy loams, silty clay and clay loams. Fifty per cent of the land is flat, 30% gently sloping, 20% too steep for arable experiments but used for agroforestry and grazing.

Experimental lay-out

Preliminary studies

In 1988/89, preliminary studies at Long Ashton aim to assess the value of making measurements in the current farm cropping sequence which is: GL : GL : WW : WC : WC : WC : OSR : WW (GL-grass ley; WW-winter wheat; WC-winter cereal; OSR-oilseed rape). Seven experimental field plots have been selected to represent different stages in this rotation, and 14 m wide strips across each plot designated as IFS areas. Initially, these IFS areas receive no insecticide, a fungicide only if considered absolutely necessary and reduced N fertiliser. Other areas in the same field plots (comparable with a Conventional system) will be used for comparisons. Data on crop growth, development and yield components, the incidence and severity of pests, diseases and weeds will be obtained, together with developmental methodology. In subsequent years, fungicides, herbicides and insecticides may be used selectively.

Future plans

If sufficient external funding is available this work will be expanded further to incorporate aspects of the work of other IOBC Working Group collaborators. Large-scale experimentaion is planned to commence in autumn 1989 with the overall objective to reduce the cost and increase environmental safety of farming arable crops in the UK. Opportunities to reduce crop protection, use of fertilisers and other agrochemicals will be investigated in experiments with crop rotation, soil management and other husbandry practices.

More specifically to:

(i) reduce pesticide costs by at least 30%: through development of integrated control for specific pests diseases and weeds

(ii) identify factors limiting the expansion of organic farming in the UK: and to develop non-chemical pest control methods

(iii) ensure that new strategies for crop protection are compatible with environment protection.

At IACR, Long Ashton, it is planned to compare the following systems and rotations, each in 2.5 ha field areas, for a period of 5 years (Table 3).

Table 3. Systems and crop rotations for future IFS studies at Long Ashton.

System/Rotation	Year 1	Year 2	Year 3	Year 4	Year 5
Integrated/Arable	OSR	WW	OPTION	FB	WW
Integrated/Ley-arable	GL	GL	WW	OSR	WW
Conventional/Arable	WW	WW	WB	OSR	WW
Conventional/Continuous	WW	WW	WW	WW	WW

WW-winter wheat; OSR-oilseed rape; FB- field beans; WB-winter barley; GL-grass ley; OPTION-winter oats, linseed, spring crops, mixed varieties.

The work will include:-

1. The use of non-inversion tillage in comparison with conventional ploughing.

2. Varieties selected for disease resistance rather than yield potential.

3. The use of varieties and species mixtures.

4. Modification of the rotation to include spring crops.

5. The possibility of cattle grazing the second grass ley.

Parameters to be measured

1. Plant growth, structure, development, yield components, yield.

2. Weed densities, pests and disease, fauna populations, earthworm activity.

3. Straw/stubble/grass incorporation: effects on above and on profile distribution and decomposition rates.

4. Soil structure, compaction, erosion, profile stability, porosity and penetration in relation to root growth.

5. Incorporation effects on organic content, microbial activity; implications for N availabilty and fertiliser requirement.

6. N levels and pesticide residues in soil and water through the profile.

7. Power requirement for cultivations (temporal).

8. All costs will be recorded.

These experimental areas will also provide opportunities for other scientists to research selectively focused components or investigate specific problems outside the main theme of the work.

Ministry of Agriculture, Fisheries and Food (MAFF)
Agricultural Development and Advisory Service (ADAS)

Long-term ecological implications of pesticide use: the Boxworth Project P.W. Greig-Smith (MAFF)

A large-scale experimental study was established in 1981 by the Ministry of Agriculture, Fisheries and Food, in collaboration with several other organisations. Located at the Boxworth Experimental Husbandry Farm in Cambridgeshire, the project has completed the originally planned seven years of study, and is now in a continuation phase with modified design. The project is based on a comparison of three pesticide programmes, applied under careful control to separate areas of the farm. These three systems were applied to winter wheat, with occasional break crops of oilseed rape. The effects of a high 'full insurance' regime were compared to those of reduced-input 'supervised' and 'integrated' programmes.

Full details of the design, methods of study and results are included in the Annual Reports of the Boxworth Project.

Experience gained in the Boxworth Project has guided strategies for future studies in the UK. Plans for new research into production and crop protection systems are being developed. These will include a range of crops and agricultural practices, investigated both by controlled, replicated trials of particular aspects, and by field-scale testing of effects within realistic farm conditions. Specific experimental treatments will depend on the crops being studied, the pesticides in current use, and the need to reflect farming practices at the time. However, treatments should include an 'insurance' pesticide regime and a 'nil insecticide' regime to establish extreme effects. Other treatments might involve techniques of integrated pest management and monitoring of pest, weed and disease thresholds at which economic damage occurs.

Assessment of environmental side-effects and testing of the efficacy of integrated production strategies will generally be approached separately. However, in all cases, the emphasis will be on inter- disciplinary research collaboration.

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