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Arable acronyms analysed – a review of integrated arable farming systems research in Western Europe

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Summary

Arable production has come under increasing economic and environmental pressures, especially in the last decade. These have derived from over-production, decreased farm incomes and a concern with the possible environmental effects of intensive pesticide use associated with such intensive cultivation. A number of long-term research programmes on integrated farming systems and their sustainability have recently been completed or are currently under way. In the UK, these include the 'Boxworth' project, 'SCARAB', 'TALISMAN', RISC, 'LINK Integrated Farming Systems', 'LIFE' and the demonstration-only programme 'LEAF'. These projects are reviewed in terms of their objectives, designs and results to date, and are compared with some parallel programmes in Germany, the Netherlands, Switzerland and France.

Key words: Western Europe, integrated farming, farming systems, Boxworth, SCARAB, TALISMAN, RISC, LINK IFS, LIFE, LEAF, Lautenbach, INTEX, Nagele, Third Way

Introduction

Since the late 1970s there has been considerable interest in reduced input or 'integrated' arable farming systems. This interest was generated because of changes in the economics of arable crop production, public pressure to reduce European Union (EU) food surpluses, environmental concerns and agronomic factors (Greig-Smith, 1992).

The price of cereals within the EU has declined in recent years although it is still maintained above the world market price through subsidies. Recently there has been pressure to reduce the level of Common Agricultural Policy (CAP) support and reduce the subsidies on international exports designated by the General Agreement on Tariffs and Trade (GATT) (Wall, 1992). The farmers' production costs, however, have steadily increased whilst the 'farm-gate' price has decreased, with the result that farmers' gross margins have declined (Murphy, 1990). The response of farmers to these changes has depended on (a) the relationship between fixed and variable costs, (b) the scope for diversification, (c) the potential yield capacity of farms and (d) farmers' personal inclination (Prew, 1993). Some farmers have already adopted reduced-input systems in direct response to economic pressures. This is, however, without the fore-knowledge of the long-term ecological and agronomic implications of such changes.

The grain surpluses which have accumulated in the EU were a result of the EU policy for European self-sufficiency in food production, food security and maintenance of farm incomes (de Wit, Huisman & Rabbinge, 1987). In addition, the huge increases in yield per unit area, achieved by the development of high-yielding varieties, high inputs of fertilisers and agrochemicals combined with mechanisation have added to this surplus. In the last three decades, for example, the area of wheat in Europe has increased only by 8–9% whereas the total production has more than doubled; the world stockpiles during this period were on average 28% of annual world consumption (Murphy, 1991). Consumption within the Organisation for Economic Co-operation and Development (OECD) countries is expected to remain static or to decrease, output is expected to rise further, but world trade is expected to increase only slightly. For example, world trade in wheat may increase by 20 million tonnes by the year 2000, but the EU alone will expect to produce 30 million tonnes in excess of consumption by the late 1990's (Murphy, 1991) without the implementation of set-aside whereby grain producers are subsidised for taking land out of production.

The environmental impact of farming which produces surpluses has also come under increased scrutiny in the last decade. As a result, in the UK new and comprehensive Codes of Good Agricultural Practice for the Protection of Water and Air have been published (Anon., 1991). The Ministry of Agriculture, Fisheries and Food (MAFF) in the UK now provides free advice on conservation and pollution matters. Area-specific schemes have been implemented to manage nitrate leaching. These include 'Nitrate Sensitive Areas' where farmers are paid to manage their nitrogen inputs to prevent leaching into ground waters. 'Nitrogen Advisory Areas' also exist for which detailed advice is given but no payments are made. Environmentally Sensitive Areas have also been established in which farmers are subsidised if they farm less intensively (Archer & Lord, 1993). On a wider scale the Countryside Commission administers the 'Countryside Stewardship Scheme' in which participants receive financial support and management advice for restoring or enhancing a range of traditional English landscapes and wildlife habitats (Anon., 1993). Pesticides have also received attention. Long-term monitoring studies by The Game Conservancy Trust have highlighted the inimical effects of modern farming methods on invertebrates and game birds such as the grey partridge (*Perdix perdix* L.) (Potts, 1986). Furthermore, of 130 species of birds which breed regularly on farmland in the UK, 16 have declined in population significantly, including nine of the 15 species which reside in the cereal ecosystem throughout the year (Marchant, Hudson, Carter & Whittington, 1990). The short- and long-term effects of pesticides on non-target invertebrates are discussed in detail in Burn (1989) and Jepson (1989). In the EU, the tolerance for pesticides in drinking water is 0.1 μg of any pesticide per litre of water (Roberts, 1989). These are the minimal detectable limits and do not reflect the toxicity of the pesticide; however, because of the high cost of purifying water the only economically viable method of achieving these limits is to change agricultural practices (Zadoks, 1992).

There are also many agronomic factors to consider. The intensive use of pesticides has led to the development of resistance in insect pests, weeds and diseases, subsequently reducing the efficacy and diversity of available crop protection products. Furthermore, products are constantly being withdrawn because of environmental and health considerations. In combination with these factors and the decline in the production of new crop protection products owing to timescale and financial constraints (Finney, 1988), fewer new products are being developed to replace those lost. The basis of most arable farming systems is inputs of non-renewable resources such as fertilisers, fossil fuels and agrochemicals. Experience in the USA has already shown that some high-input farming systems can result in decreasing soil productivity, declining environmental quality, reduced profitability and threats to human and animal health (Reganold, Papendick & Parr, 1990).

The main response in the EU to excessive grain production has been a reduction in production-coupled subsidies, downward adjustment of price-support mechanisms and the implementation of set-aside (Potts, 1991). Set-aside schemes aim to take 15% of arable land out of food production on an annual rotational basis or 18% in a non-rotational scheme. This, however, may prove to be economically and socially unacceptable and may lead to intensification (higher inputs of agrochemicals giving greater production per unit area). The European Parliament has recognised this and foresees set-aside as a transition to ecologically sound farming, i.e. extensification, which involves lower inputs of agrochemicals and hence lower production (Potts, 1991). Extensification may be achieved through the development of integrated farming practices, but the majority of research on integrated production in the EU until the late 1970's was conducted on a relatively small scale and was limited to specific aspects of the crop production system. Jordan (1989) listed many of the studies carried out in the UK on integrated production. A crop environment is, however, a highly interactive system and needs to be investigated as such. For example, nitrogen inputs affect crop physiology and subsequently susceptibility to pests and diseases (Vereijken, 1989*a*); ultimately the interaction of these determines yield and quality. Therefore any investigation of farming systems must assess all aspects of crop production if it is to be fully understood. These conclusions were drawn at an International Organisation of Biocontrol/West Palaearctic Region Sector (IOBC/WPRS) meeting in 1976 with the result that a study group was set up in 1981 to examine the possibility of developing research programmes on 'management of experimental farming systems for integrated crop protection'. This group compiled guidelines for the design of experiments on integrated farming systems (Vereijken, 1986) and an IOBC/WPRS working group for integrated arable farming was initiated with researchers from nine countries (Vereijken, 1989*a*). This led to a number of projects on integrated farming being established. Descriptions of these projects are available in Vereijken & Royle (1989). In 1993 this group produced 'Guidelines for Integrated Crop Production' (El Titi, Boller & Gendrier, 1993). The opportunities that integrated farming may offer led to the establishment of long-term experiments at Nagele (the Netherlands) and Lautenbach (Germany) in the late 1970's. In the UK the Boxworth project was the first large-scale, long-term experiment in which different farming systems were examined. Results from these experiments are now available and a number of other projects are under way. Some of these appear to have similar aims and designs. Each of the major projects in the UK and a range of projects in continental Europe are reviewed here in terms of their aims, methodology and main results. The key references on which these appraisals are based are given in Table 1. Experimental farms have also been established in Ireland (Johnstone), Italy (Florence) and Sweden (Logården and Alnarp) while others are planned in each of the other EC-member countries.

The Boxworth Project (1981–1988)

Background

The 1970's was a decade of increasing pesticide (fungicides, herbicides, insecticides, molluscicides and nematicides) use in UK cereals (Sly, 1981) and during this time an overall decline in cereal invertebrates was observed in southern England (Aebischer, 1991). There was no direct proof that these trends were connected but the possibility of a link, together with an increase in the frequency of applications per season and the increasing use of pesticide mixtures, raised concern that intensive pesticide use in cereals could be environmentally damaging.

Table 1. *Key references describing the arable farming systems research projects reviewed*

Project	References
Boxworth	Greig-Smith (1991)
	Greig-Smith & Hardy (1992)
	Greig-Smith *et al.* (1992)
SCARAB	SCARAB Annual reports (Unpubl.)
	Cooper (1990)
	Frampton & Cilgi (1992, 1993, 1994)
TALISMAN	TALISMAN Annual reports (Unpubl.)
	Cooper (1990)
	Jordan, Hutcheon & Perks (1990)
	Perks & Lane (1990)
RISC	RISC Annual reports (Unpubl.)
	Easson (1993)
LIFE	Jordan (1989, 1990)
	Jordan *et al.* (1990, 1993)
	Jordan & Hutcheon (1994*a*, *b*)
LINK IFS	LINK IFS Annual reports (Unpubl.)
	Holland (1994)
	Prew (1993)
	Wall (1992)
LEAF	Abel & Hill (1993)
Lautenbach	El Titi (1986, 1989, 1990, 1991)
	El Titi & Landes (1990)
INTEX	Gerowitt & Steinmann (1992)
	Przemeck & Lickfett (1992)
	Schmidt & Waldhardt (1992)
	Stippich & Büchner (1992)
	Wildenhayn (1992)
Netherlands	Vereijken (1985, 1989*a*, *b*, 1990)
	Wijnands & Vereijken (1986, 1992)
	Wijnands (1990, 1992)
Third Way	Häni (1989, 1990, 1993)
France	Viaux, Roturier & Bouchet (1993)

The Boxworth project was set up to investigate the effects of this intensive use of pesticides in cereals on a range of wildlife including plants, birds, small mammals and arthropods. The first large-scale study in the UK to involve a long-term comparison of different farming systems, it was funded by the MAFF and undertaken in collaboration with a number of research organisations. The Boxworth project was concerned primarily with the environmental consequences of pesticide inputs; the study of other aspects of integrated farming systems, such as disease-resistant varieties and variety mixtures, occupied only a small part of the project (Greig-Smith, Frampton & Hardy, 1992). The main aim was to investigate the long-term impact of three pesticide regimes on farmland wildlife. There were also two subsidiary aims: to make economic comparisons between the three regimes and to assess their management (Greig-Smith & Griffin, 1992).

Design and methods

The project was sited at Boxworth Research Centre, a MAFF cereal farm in eastern England. The farm was divided into three units, each a block of contiguous fields (see Table 2 for summary of experimental design). This was to allow realistic monitoring of the effects

Table 2. *Summary of experimental designs for the arable farming systems research projects reviewed (see text for details)*

Project	Number of sites	Regimes	Experimental design	No. of replicates per treatment/year	Size of each experimental unit	Additional small sub-plot validation trials
Boxworth	1	Full insurance	Four contiguous fields	1	12–15.6 ha	Yes
		Supervised	Four contiguous fields	1	11.5–17.3 ha	
		Integrated	Three contiguous fields	1	5.7–10.7 ha	
SCARAB	3	Current farm practice	Seven paired half-fields	1	4–16 ha	No
		Reduced input approach				
TALISMAN	3	(See Table 6*a*)	Six–12 randomised blocks per site	3–4	18 × 20 m (min.)	Yes
RISC	2	(See Table 6*a*)	12 randomised blocks per site	4	10 × 40 or10 × 20 m	Yes
LIFE	1	Current farm practice/CR	Five paired blocks	5	100 × 48 m	Yes
		Integrated farming system/CR				
		Current farm practice/IR				
		Integrated farming system/IR				
LINK IFS	6	Conventional farming practice	Seven–nine paired blocks per site	1–3	>2.5 ha (>72 m wide)	Yes
		Integrated farming system				
LEAF	6	Integrated farming system	Whole farm non-experimental			
Lautenbach	1	Current farming system	Six paired blocks	1	4 or 8 ha	No
		Integrated farming system				
INTEX	3	I. Conventional/high input		1	1.2–3.8 ha	No
		II. Integrated				
		III. Reduced				
		IV. Extensive				
		V. Fallow				
The Netherlands						
1. Nagele	1	Conventional/arable	Three whole farm comparisons	1	2 ha	No
		Integrated/arable				
		Organic/mixed				
2. Borgeswold	1	Conventional	Three whole farm comparisons	1	2 ha	No
		Conventional/LR				
		Integrated/LR				
3. Vredepeel	1	Conventional	Four whole farm comparisons	1	2 ha	No
		Integrated				
		Integrated/LR				
		Integrated/MR				
Third Way	3	Integrated	Comparison of conventional and	1	16, 20 and 10 ha	No
		Conventional	no pesticide areas with remainder	1	12 m wide strips	
			of field and comparison of	1	12 × 30 m block	
			integrated and conventional farms			
			of similar structure			
France	4	Conventional	Six–10 paired blocks per site with	1	1–5 ha	No
		Integrated	rotations in deep and shallow soils			

CR = conventional rotation, IR = integrated rotation, LR = less root crops, MR = more root crops.

Table 3. *Summary of husbandry practices in each arable farming systems research project (see text for details)*

Project	Regime	Rotation	Cultivation	Sowing dates	Varieties	Fertiliser regime	Pesticide regime	Cover crops	Field margin management
Boxworth	FI	WW or WW (4 yrs) + BC	Plough	Standard	High yielding	Standard	Prophylactic	No	No
	SUP	WW or WW (4 yrs) + BC	Plough		High yielding	Standard	Reduced	No	No
	INT	WW or WW (4 yrs) + BC	Plough		Disease resistant	Standard	Reduced	No	No
SCARAB	CFP	Cereals (2 yrs)/BC/cereals (2 yrs)	Plough	Standard	High Yielding	'Fertiplan'	Standard	No	No
	RIA	Cereals (2 yrs)/BC/cereals (2 yrs)	Plough		High yielding	'Fertiplan'	Reduced (no insecticides)	No	No
TALISMAN	CCP-s	BC/cereals (2 yrs)/BC/cereals	Variable	Standard	High yield	'Fertiplan'	Standard	No	No
	LIA-s	BC/cereals (2 yrs)/BC/cereals	Variable		High yield	50% reduction	>50% reduction	No	No
	CCP-a	Different BC + spring cereals	Variable		Disease resistant	'Fertiplan'	Standard	No	No
	LIA-a	Different BC + spring cereals	Variable		Disease resistant	50% reduction	>50% reduction	No	No
RISC	CFP-s	BC/cereals (2 yrs)/BC/cereals	Variable	Standard	High yield	'DANI'	Standard	No	No
	LIA-s	BC/cereals (2 yrs)/BC/cereals	Variable	Standard	High yield	Up to 50% of CFP	Up to 50% of CFP	No	No
	CFP-a	2 yr pasture/P/WW/SB/WB	Variable	Standard	High yield	Up to 50% of CFP	Up to 50% of CFP	No	No
	LIA-a	2 yr pasture/P/WW/SB/WB	Variable	Standard	High yield	Up to 50% of CFP	Up to 50% of CFP	No	No
	INT-s	BC/cereals (2 yrs)/BC/cereals	Variable	Late	Disease resistant	Up to 50% of CFP	Up to 50% of CFP	Yes	No
	INT-a	2 yr pasture/P/WW/SB/WB	Variable	Late	Disease resistant	Up to 50% of CFP	Up to 50% of CFP	Yes	No
	MIN-s	BC/cereals (2 yrs)/BC/cereals	Variable	Late	Disease resistant	Minimum	As last resort	Yes	No
	MIN-a	2 yr pasture/P/WW/SB/WB	Variable	Late	Disease resistant	Organic	As last resort	Yes	No
LIFE	CFP	Cereals + BC + SAS 4-course	Plough	Standard	High yielding	Standard	Standard	No	No
	IFS	Cereals + BC's + SAS 5-course	Reduced tillage	Late	Resistant	'N-sampling'	Reduced	Yes	Yes
LINK IFS	CFP	Cereals + BC's + SAS 5-course	Plough	Standard	High yield	'Fertiplan'	Standard	No	No
	IFS	Different BC's at some sites	Plough or reduced tillage	Late	Resistant	'N-sampling'	Reduced	Yes	Yes
LEAF	IFS	Varies	Reduced tillage	Late	Resistant	Reduction	Reduced	Yes	Yes
Lautenbach	CFS	Cereals + BC's 6-course	Plough	Standard	Seed crop	Optimum	Standard	No	No
	IFS	Cereals + BC's 6-course (winter + spring sown)	Non-inversion		Seed crop	25% reduction	Reduced	No	Yes

INTEX	I	OSR/WW/WB 3-course	Plough	Standard	High yielding	Standard	Standard	No	No
	II	OSR/WW/FB/WB 4-course	Reduced tillage	Late	Mixed/resistant	70% reduction	Reduced	No	Yes
	III	OSR/WW/WB 3-course	Plough	Standard	High yielding	50% reduction	No insecticide	No	No
	IV	OSR/WW/FB/WB 4-course	Reduced tillage	Late	Mixed/resistant	None	None	No	Yes
	V	Fallow							
Nagele	CFP	P/?/SBe/WW 4-course	Plough	Standard	High yielding	Standard	Standard	Yes	No
	IFS	P/?/SBe/WW 4-course	Reduced tillage	Late	Resistant	Reduced + organic	Reduced	Yes	No
	Org	P/WW/Carrot/3 yr pasture	Minimal	Late	Resistant	Organic	Organic only	Yes	No
Borgeswold	CFP	P/SBe/P/WW	Plough	Standard	High yielding	Standard	Standard	Yes	No
	CFP/LR	P/SW/Peas/Grass seed/P/FB/SBe/WW	Plough	Standard	High yielding	Standard	Standard	Yes	No
	IFS/LR	P/SW/Peas/Grass seed/P/FB/SBe/WW	Reduced tillage	Late	Resistant	Reduced + organic	Reduced	Yes	No
Vredepeel	CFP	P/SBe/WW/S/P/SBe/M/Pea or B	Plough	Standard	High yielding	Standard	Standard	No	No
	IFS	P/SBe/WW/S/P/SBe/M/Pea or B	Reduced tillage	Late	Resistant	Reduced + organic	Reduced	Yes	No
	IFS/LR	P/SBe/WW/S/P/M/Pea/Grass seed	Reduced tillage	Late	Resistant	Reduced + organic	Reduced	Yes	No
	IFS/MR	P/SBe/WW/S/P/SBe/Carrot/Pea or B	Reduced tillage	Late	Resistant	Reduced + organic	Reduced	Yes	No
Third Way CFP = IFS = WPs	CFP	Varies with farm but same for each regime	Plough	Standard	High yielding	Optimum	Standard	No	No
	IFS		Reduced tillage	Late	Resistant/mixed	Reduced	As last resort	Yes	Yes
	WPs		Reduced tillage	Late	Resistant/mixed	Reduced	None	Yes	Yes
France	CFP	Cereals + BC minimum 3-course	Plough	Standard	High yielding	Optimum	Standard	No	No
	IFS	Cereals + BC minimum 3-course	Shallow	Late	Resistant	Reduced	Reduced	No	No

FI = full insurance regime, SUP = supervised regime, INT = integrated regime, CFP = conventional farm practice, RIA = reduced input approach, CCP = current commercial practice (-s = standard rotation, -a = alternative rotation), LIA = low input approach, MIN = Minimum Inputs, IFS = integrated farming system, Org = organic, WPs = without pesticides, LR = less root crops, MR = more root crops, WW = winter wheat, BC = break crop, OSR = oilseed rape, SB = spring barley, WB = winter barley, SAS = set-aside, FB = field beans, M = maize, P = potatoes, SBe = sugar beet, S = scorzonera, B = dwarf beans.

of pesticide use on mobile animals such as birds and small mammals. Each unit received one of three pesticide regimes during the treatment phase of the project (1983–1988). These were: (1) a 'full insurance' programme which involved high inputs and prophylactic treatments, imitating an intensive cereal production system of the late 1970's; (2) a 'supervised' programme whereby pesticides were applied only if weeds, diseases and pests exceeded economic thresholds; (3) an 'integrated' regime using economic thresholds and husbandry practices which further reduced the need for pesticides. In practice there was little difference between the supervised and integrated regimes in terms of their pesticide inputs. Effects of fertiliser inputs were not investigated. At the start of the project (1981–1983) all three experimental units received a 'supervised' pesticide regime to allow "baseline" monitoring of wildlife to be undertaken before the contrasting pesticide inputs were implemented.

It was decided at the outset to keep the pesticide regimes constant throughout the experimental period, even though current farming practices may have changed during the programme. Continuous winter wheat was grown throughout the experimental period with the exception of an oilseed-rape break crop every five years. Further details of the experimental design and research programme are shown in Tables 2 to 4 respectively.

Principal results

The detailed results of the Boxworth project were reviewed in Greig-Smith *et al.* (1992) and are summarised below and in Table 5.

Some beneficial epigeal arthropods virtually disappeared from full insurance fields for the full five-year treatment phase of the project while others were less adversely affected (Vickerman, 1992). These inter-specific differences in responses were attributed to differences in species' exposure to pesticides as a result of differences in their ecology, life-cycles and dispersal abilities (Burn, 1992; Vickerman, 1992). Effects of the full insurance regime on soil fauna also varied, with some species adversely affected and others apparently favoured (Frampton, Langton, Greig-Smith & Hardy, 1992). Overall, densities of herbivores and carnivores (predators and parasitoids) were approximately 50% lower in the full insurance than in the supervised and integrated regime fields, although detritivores did not show an overall adverse effect as a result of the full insurance regime (Vickerman, 1992). Some pest species were not always adversely affected; in some years populations of the grain aphid *Sitobion avenae* (F.) and rose-grain aphid *Metopolophium dirhodum* (Wlk.) (Homoptera) were highest in full insurance fields, perhaps reflecting lower numbers of predators; Burn (1992) showed that the full insurance regime reduced the predatory impact of the invertebrate fauna on artificial pest baits (Diptera pupae) and on aphid populations in some years.

Of the other wildlife monitored at Boxworth, lethal effects of pesticide use were detected only in wood mice (*Apodemus sylvaticus* L.), which were killed by broadcast molluscicide pellets (Johnson, Flowerdew & Hare, 1992). Some birds were exposed to organophosphorus insecticides (Hart *et al.*, 1992; Thompson, Tarrant & Hart, 1992) but there was no conclusive evidence of an overall effect of the pesticide regimes on the breeding performance of the most common bird species (Fletcher, Jones, Greig-Smith & Hardy, 1992), nor on populations of rabbits (Tarrant & Thompson, 1992) or wild plants (Marshall, 1992).

Monitoring crop performance showed that the full insurance regime usually gave the highest yields but the supervised regime was equally, if not more profitable, despite lower yields. The integrated regime gave the lowest yields and lowest gross margins and attempts to reduce herbicide inputs below those of the supervised regime caused problems with grass weeds (Jarvis, 1992). However, as the integrated regime at Boxworth was a compromise

Table 4. *Summary of research components of each arable farming systems research project*

		Agronomics				Environment					
Project	Economics	Weeds	Pests	Diseases	Soil minerals	Non-target invertebrates	Birds	Mammals	Earthworms	Soil micro-biology	Pesticide residues
Boxworth	*	*	*	*		*	*	*			*
SCARAB	*	*	*	*		*			*	*	
TALISMAN	*	*	*	*	*	*					
RISC	*	*	*	*	*	*					
LIFE	*	*	*	*	*	*			*	*	
LINK IFS	*	*	*	*	*	*			*		
LEAF	*										
Lautenbach	*	*	*	*	*	*		*	*	*	
INTEX	*	*	*	*	*	*		*	*	*	*
Netherlands	*	*	*	*	*	*	*	*	*	*	
Third Way	*	*	*	*	*				*	*	
France	*	*	*	*	*						

*Studied.

Table 5. *Summary of results*[1] *for integrated farming compared with the conventional practice for each project reviewed here*

	Economics		Agronomics								Environment				
Project	Yield	Gross margin	Nitrogen	H	F	I	PGR	Weeds	Pests	Soil-borne diseases	Beneficial arthropods	Birds & mammals	Earthworms	Soil microorganisms	Soil minerals
Boxworth	–	–		–	–	–	=	+	+	O	+	O			
SCARAB	–	+		–	–	–	=	+	=		+		O	O	
TALISMAN	O	O	–	–	–	–	–	O	O	O	=				
RISC	O	O	–	–	–	–	–	O	O	O	O				
LIFE	–	+	–	–	–	–	–	+	=	=	+		+	=	=
LINK IFS	No results to date														
LEAF	No results to date														
Lautenbach	–	+	–	–	–	–		+	–	O	+		+		=
INTEX	–							–		+	+				
Netherlands	–	=	–	–	–	–	–	+			+	+	+		=
Third Way	O	O	–	–	–	–	–	+	O		+		+	+	
France	O	O	–	+	–	–	–	+	O						

H = herbicides, F = fungicides, I = insecticides, PGR = plant growth regulators, '+' = increase, '–' = decrease, '=' = no change, 'O' = variable result, '?' = insufficient information to date.

[1] Results presented here indicate general trends; variation within individual studies occurred.