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Alternative Farming Methods (Arable - Phase 2)

A study of the effects of an Integrated Arable Management System on levels of herbicide and nutrients reaching Controlled Waters

IACR Long Ashton

R&D Technical Report P113

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ALTERNATIVE FARMING METHODS (ARABLE)

A Study of the Effects of an
Integrated Arable Management
System on Levels of Herbicide
and Nutrients Reaching
"Controlled Waters"

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Research Contractor:
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R&D Technical Report P113

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APPENDIX

EXECUTIVE SUMMARY

1. This document summarises the data gained, results and conclusions of a research project investigating the influence and impact of different soil management practices adopted in conventional integrated crop management(ICM) and advanced integrated arable crop production systems on selected herbicide and nutrient emissions in drain water discharged from fields of the IACR-Long Ashton Research Station "LIFE" Project between October 1995 and April 1997. Monitoring data for the winter of 1995/96 has already been reported (see R&D Technical Report P17).

- **The results herein confirm that even when more conventional "integrated techniques" (ICM) have been adopted, there are further gains to be made in reducing inputs and drainage losses by adopting more "advanced integrated techniques" (IFS), whilst maintaining profitability.**

2. The main purpose of the project was to monitor levels of total oxidised nitrogen and soluble phosphate, and of autumn-applied herbicides (isoproturon, diflufenican, and simazine from a conventional field in 1997) in drain water discharges from fields that were either established using the traditional plough then farmed conventionally or from adjacent fields where crops were established by soil conservation tillage systems and grown under advanced integrated production(IFS) guidelines.

3. The project aimed to measure the herbicide and nutrient concentrations in drain water discharges that emanated from the conventional and alternative integrated systems of production. All chemicals and nutrients were applied by tractor-mounted sprayers, and according to good agricultural practice. Measurements were taken pre- and post-herbicide application during drain flow, and in response to rainfall events.

4. Over the two monitoring years (1995-1997), substantial and consistent reductions in total oxidised nitrogen and soluble phosphate emissions were obtained from the integrated production system (IFS) fields in which soil conservation tillage (non-inversion) practices were used for crop establishment.

5. Total oxidised nitrogen emissions in drain water discharges from field units between December 1995 and February 1996 showed that the average loading losses from the IFS system were 82% lower than the ICM system.

6. Total oxidised nitrogen emissions in drain water discharges from field units between November 1996 and February 1997 showed that the average loading losses from the IFS system were 87% lower than the ICM system.

7. On the first occasion when field drains ran in December 1995, the soluble phosphate in the IFS drains (46 ugP/l) was much lower than the ICM drains (165ugP/l). Thereafter, levels were low (< 10 ugP/l) from both systems, but nevertheless, when averaged over the whole sampling period, soluble phosphate loading was 81% lower in discharges from the IFS system.

8. On the first occasion when field drains ran in November 1996, the soluble phosphate loading was only 26% lower in the IFS field drains than that from the ICM drains. Thereafter, loadings from the IFS system were between 52% and 88% lower than the ICM system.

9. In autumn 1995, isoproturon was applied at the recommended rate to the conventional production system, and at a reduced rate to the integrated systems. During the 1995/1996 sampling period, isoproturon was only detected in drain water discharges (range 0.19 -0.36 ug/l) from the conventional production system. Isoproturon did not exceed detection limits (0.08 ug/l) in any drain water discharged from the integrated production system fields.

10. In autumn 1996, as field beans were grown in the conventional field isoproturon was not used, but it was applied to the two integrated production field units, either at the full recommended rate or at reduced (½) rate. It only exceeded detection limits on the first sampling occasion after application, and only then in the drainwater discharged from the integrated field unit that received the full rate of isoproturon.

11. In both years, diflufenican did not exceed detection limits (0.02 ug/l) in any drain water discharge sample taken following field application at the IFS dose rate.

12. Whilst no comparable results were available for the IFS fields, results obtained for simazine losses in 1997 confirm that simazine poses a high risk of leaching from agricultural land that is ploughed.

Key Words: agriculture, conventional production, integrated farming systems(IFS), non-inversion tillage, herbicides, nitrate, phosphate, pollution, water quality.

BACKGROUND.

IACR Long Ashton has been pioneering research into less-intensive farming and environmental protection in the UK (the LIFE Project) as part of a European network of integrated farming systems research, and in response to current/future National and European agricultural policy requirements. The objectives of the LIFE project are to provide fundamental information on effects, interactions and ecological/environmental implications f alternative arable production systems which are economically and ecologically sound, more environmentally benign, and sustainable in the long term. Based on data generated since 1989, an integrated farming systems approach has been identified as a practical option to sustain production, maintain the competitiveness of farmers and farm income, and to safeguard the environment (Jordan & Hutcheon 1993;1994). This, with support from MAFF and CEC (DGVI), is now being researched and developed further at IACR-Long Ashton, and being evaluated in commercial practice.

The following report presents data on the quality of water draining from selected LIFE experimental field units at Long Ashton, over a period from October 1995 - April 1997, in response to application timing and rainfall events.

1. OBJECTIVES.

The overall objective of the project is to provide data on the effects of the different soil management and agrochemical input levels used in conventional integrated crop management practice (ICM) and advanced integrated production systems (IFS) on herbicide and nutrient emissions in drain water discharges, and their implications for water quality. Furthermore, to demonstrate that an alternative and integrated approach to arable crop management, reliant upon soil conservation tillage practices for crop establishment, can minimise/reduce levels of certain agrochemicals and nutrients reaching "controlled waters".

More specifically, and using selected herbicides and nutrients as response indicators, the project aims to provide quantitative information on the comparative effects and interactions of conventional tillage (ploughing) and conservation soil management (non-inversion tillage) practices used for crop establishment in the different systems, together with differing levels of agrochemical and nutrient inputs, on agrochemical emissions and concentrations in drainwater, and their effects on the water environment. In addition, attempts will be made to qualify and quantify the amounts of the response indicators exported from the system comparisons in order to provide indications of the influence, relationship and contributions of some specific component practices adopted.

To address these objectives, advance integrated production systems use lower amounts of applied nutrients, and are reliant upon soil conservation techniques and minimum intervention for crop establishment. The monitoring of nutrient emissions (total oxidised nitrogen and soluble phosphate) should also provide an indication of differences between current conventional and alternative systems of production and farming practices.

2. SITE LOCATION

2.1 The LIFE Project: Field 56 - Wraxall, Nr Bristol.

The study site (Field 56 at Wraxall) is part of the IACR-Long Ashton Research Station LIFE Project, which is a long-term, farm scale experiment occupying 23 ha, and where comparisons of conventional and less-intensive integrated farming systems approaches have been under investigation since 1989. In autumn 1994, Phase II of the LIFE systems comparison commenced and compares a conventional(ICM) system with advanced less-intensive integrated production over a fully-phased, 7-course multifunctional crop rotation (wheat : oilseed rape : wheat : barley/oats : set-aside : wheat : beans).
Within the LIFE Project, Field 56 is a North-facing field with a 4.5° rectilinear slope. It is divided into four Field Units (561, 562, 563, 564) of approximately 1 ha each in size, offering the best opportunity to meet the project objectives. Within this field, with seasonal groundwater table between 80 - 120cm, 60mm PVC drainage pipes were inserted in the lower 80m of each field unit, spaced at 12m intervals (running along each tramline) to a depth of 1m, in autumn 1989, with outflows into an adjacent ditch (Figure 1).

3. CROP MANAGEMENT STRATEGIES

Crop management practices, inputs and productivity for the four field units during 1994/95, prior to the start of this study are given in Appendix 1.

3.1 Conventional Production(ICM) System - Field Unit 561; 1995-1996.

On 16 September 1995, this field received a primary cultivation (Simba Maximix) after the previous winter oilseed rape crop, was ploughed on 23 September and drilled with winter wheat, cv. Hereward, on 28 September 1995 following two springtine cultivations. Herbicide (isoproturon + diflufenican) was applied on 1 November, and the crop managed thereafter (from March 1996) by conventional crop management practice (Appendix 2).

3.2 Integrated Production(IFS) System - Field Unit 564; 1995-1996.

In the contrasting system, Field Unit 564, winter wheat, cv Spark, was established following one primary cultivation (Simba Maximix) on 10 September 1995 and sown, using a one-pass non-inversion tillage system (Dutzi) on 9 October 1995. For the comparative purposes of this study, the same herbicides were applied to the integrated wheat crop, but at half the rate of active ingredient applied to the conventional Field Unit (561). Thereafter, the crop was managed according to the guidelines for less-intensive, integrated production (Appendix 2).

The two central Field Units in this field, (562 and 563) remained as natural regeneration (weeds and volunteers), and were sown with either spring oilseed rape or spring beans in March 1996.

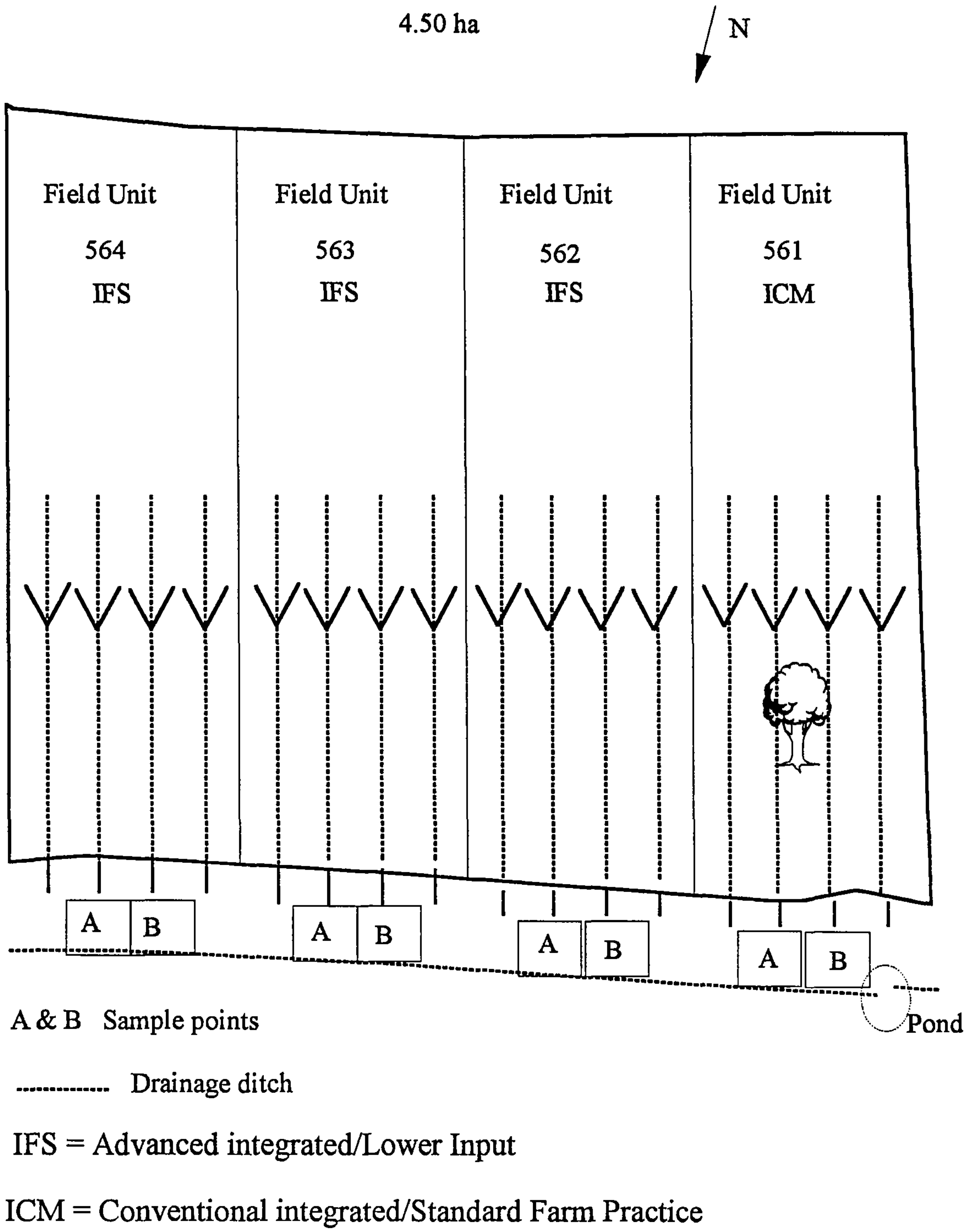

Figure 1. Layout of field drains in LIFE Field 56.

3.3 Conventional Production(ICM) System - Field Unit 561; 1996-1997.

On 10 September 1996, basal fertiliser (0:24:24) was applied, and the field ploughed on 25 September. It received a springtine cultivation on 26 September, and again on 13 November to level the field, make a deep seedbed and kill volunteers and weeds. It was drilled with winter beans, cv. Punch, on 14 November using a Vaderstad drill. Simazine (750g a.i/ha) was applied on 21 January and the crop had emerged by 6 February 1997 (Appendix 3).

3.4 Integrated Production(IFS) System I - Field Unit 562; 1996-1997.

Current strategies dictate that oilseed rape fields are not cultivated post harvest, to avoid incorporation of shed seed, thereby limiting the future volunteer rape seed bank. It also permits more rapid germination of rape volunteers. Therefore, in the adjacent Field Unit (562), the germinated rape volunteers were sprayed with glyphosate on 2 October 1996 and winter wheat, cv. Genesis, was sown in one pass with non-inversion tillage (Dutzi) on 23 October. For the purposes of this experiment, the IFS rate of isoproturon + diflufenican (1000g.a.i/ha + 25g a.i./ha) was applied on 6 December and the field received no further treatments until 28 March, when drainflow had ceased (Appendix 3).

3.5 Integrated Production(IFS) System II - Field Unit 563; 1996-1997.

As part of the rotational weed control policy, the next IFS Field Unit (563), was Dynadrived on 10 September to promote weed seed germination, then and again on 1 October for mechanical weed control, and sown with winter wheat, cv. Reaper, in one-pass with non-inversion tillage (Vaderstad) on 2 October 1996. For the comparative purposes of this experiment, this Field Unit received the commercial rate of isoproturon + diflufenican (2000g.a.i/ha + 25g a.i./ha) was applied on 6 December and the field received no further treatments until 29 March, when drainflow had ceased (Appendix 2).

4. METHODOLOGY

4.1 Drain water discharge sampling.

On each occasion when field drains ran, water samples (2 litres) were taken from each drain outlet from the two central field drains in each field unit, with the outside two drains acting as appropriate buffers between field units. The drain water flow rate was measured on each occasion as the time taken to fill a 1 litre measuring cylinder. Although initially, five event-triggered (15mm rain) and two routine samples were planned in the first sampling year, following specific herbicide treatments, the prevailing weather conditions during autumn 1995 limited the frequency of occasions when drainflow occurred. Thus samples were taken on each drainflow event, and analysed for nutrient and herbicide content. In the 1996/1997 sampling year, drainflow occurred on 10 occasions between 25 November 1996 and 24 February 1997 with samples taken on each occasion. The daily rainfall amounts during the sampling period are shown in Figure 2.

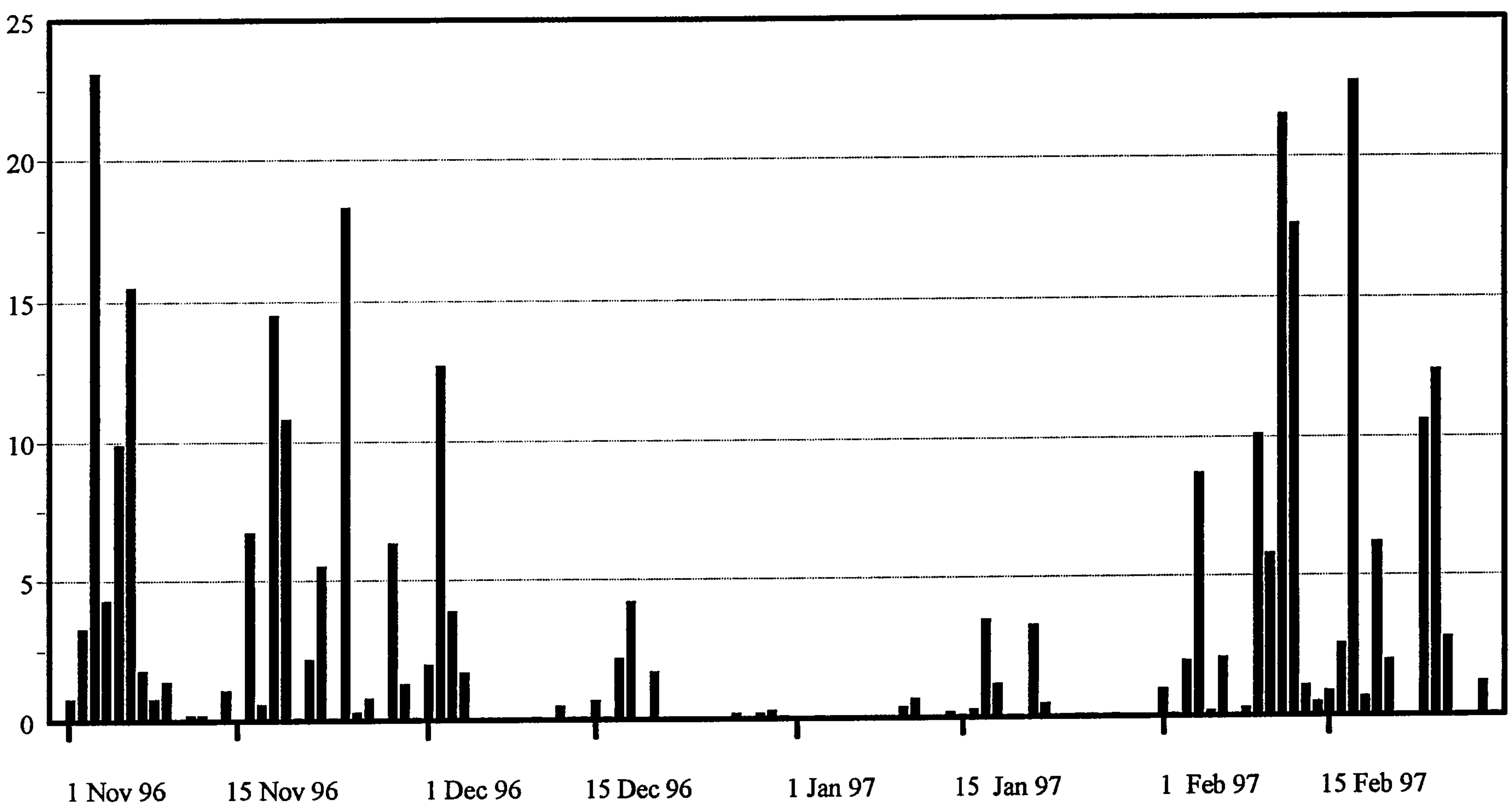

Figure 2. Rainfall(mm) event data during the 1996/97 sampling period.

4.2. Analytical Methods.

Determination of diflufenican

One litre of each sample was extracted with 2 x 25ml + 1 x 15ml n-hexane. The three extracts were combined, dried over anhydrous sodium sulphate, and evaporated down to 200ul in a stream of dry nitrogen. Samples were analysed using a GC Column: 25m x 0.32mm BPI(0.25u)-SGE

Determination of isoproturon

500ml of each sample was passed through a conditioned Extract-Clean C18 column (500mg.6.0ml - Alltech)[1] or Supelclean ENVI - 18SPE tube (500mg/6.0ml - Supelco)[2]. The tubes were eluted with 4.0ml HPLC grade methanol and the extract concentrated to 1.0ml in a stream of nitrogen. Samples were analysed using a LDC/Milton Roy HPLC

4.3. Examination of Water Samples for selected nutrients.

Low level orthophosphate

Filtered aqueous samples were injected into a carrier stream and merged with acidic ammonium molybdate reagent solution to form heteropoly acid. The heteropoly acid is then reduced to molybdenum blue by adding acidic stannous chloride in a second reagent stream. The developed colour is measured spectrophotometrically at 674nm, using a Tecator FIAstar flow injection analyser. Injection volume - 260ul, injection time - 20 sec, delay time- 30 sec, cycle time - 50 sec, sample throughput 70h; range 5 - 100 ug/l P (detection limit 2ug/l).

Total oxidised nitrogen

Nitrate is reduced quantitatively to nitrite by passing the sample through a copperised cadmium reductor(coil). The nitrite thus formed, plus any originally present reacts with sulphanilamide in an acidic solution to form a diazo compound. The diazotised product is then coupled with N-(1- naphthyl)-ethylenediamide dihydrochloride. The intensity of the formed azo dye is then measured at 540nm. Turbid samples are pre-filtered through a 0.45um membrane prior to analysis. EDTA is added to eliminate interference from iron, copper or other metals. Range 0.001-100mg/l; precision 0.05mg/l; detection limit 0.001mg/l.

5. RESULTS

5.1. Autumn applied herbicides in drainwater discharges; 1995-1996

The soil water deficit following the 1995 dry summer and the subsequent lack of rain during autumn limited the frequency of discharges from drain outlets and, hence, sampling occasions.
Discharges from drain outlets first occurred on 20 December 1995, 50 days after field application of herbicides. The field drains ran again two days later, then not again until 2 January 1996. Thereafter, discharges occurred on 5 and 12 January, but only from drain outlets in the Conventional Production System (Field Unit 561). No further discharges occurred on this site throughout spring and summer 1996.

On the first sampling occasion, 20 December 1995, isoproturon concentrations did not exceed detection limits (0.08 ug/l). Isoproturon (range 0.19 - 0.36 ug/l) was detected in drain water discharge samples from the conventional system at the four sampling occasion thereafter (Table 1), but it did not exceed detection limits in any drain water discharged from the integrated production system (Table 2). Although the limited drain flow frequency during autumn and winter reduced the number of sampling occasions, substantial reductions were obtained in the losses of isoproturon in drain discharges from the integrated production system compared to the conventional system.

Diflufenican did not exceed detection limits (0.02 ug/l) in any sample taken.

5.2. Autumn applied herbicides in drainwater discharges; 1996-1997

Discharges from drain outlets first occurred on 25 November 1996 and ran again on 3 December 1996 prior to herbicide application on 6 December 1996. The first drain water discharge after field application of herbicide occurred on 12 February and on 7 occasions thereafter until 24 February, after which drainflow ceased. In the integrated production field unit that received the higher (recommended) rate of isoproturon (2000g.a.i./ha), isoproturon only exceeded detection limits in one of the replicate drain water discharge samples taken on the first occasion that drain flow occurred post-application (2 months later) but not on any other occasion thereafter (Table 3). It did not exceed detection limits in any of the drain water discharge samples taken from the integrated field that received the IFS (½) rate of isoproturon (Table 4). Diflufenican did not exceed detection limits (0.02 ug/l) in any drain water discharge sample taken following application at the IFS dose rate (Table 3), and on only one occasion when applied at the ICM recommended dose rate (Table 4).

Table 1. Summary of event data and measured concentrations of isoproturon in drainflow water emanating from Conventional(ICM) production systems 1995-1996

Date	Drainflow Rate (l/min)	Isoproturon (ug)	
		concn./l	loading/sec
20 Dec 95	3.375	ND	ND
22 Dec 95	5.850	0.36	0.035
02 Jan 96	1.481	0.19	0.005
05 Jan 96	0.632	0.29	0.003
12 Jan 96	2.550	0.27	0.011
12 Feb 96	Res.sample *	ND	ND
Overall Mean	2.776	0.222	0.011

ND - below detection limits (0.08ug/l)
* Res.sample - accumulated drainage 01/02 - 12/02/96 (reservoir sample)

Table 2. Summary of event data and measured concentrations of isoproturon in drainflow water emanating from Integrated(IFS) production systems 1995-1996

Date	Drainflow Rate (l/min)	Isoproturon (ug)	
		concn./l	loading/sec
20 Dec 95	1.130	ND	ND
22 Dec 95	1.830	ND	ND
02 Jan 96	0.310	ND	ND
05 Jan 96	no flow	nt	nt
12 Jan 96	no flow	nt	nt
12 Feb 96	Res.sample *	ND	ND
Overall Mean	1.090	ND	ND

ND - below detection limits (0.08ug/l); nt - not tested.
* Res.sample - accumulated drainage 01/02 - 12/02/96 (reservoir sample)

Table 3. Summary of event data and measured concentrations of simazine in drainflow water emanating from Conventional(ICM) production systems 1996-1997

Date	Drainflow Rate (l/min)		simazine (ng)	
			concn./l	loading/sec
25 Nov 96	a.	0.932	ND	ND
	b.	1.818	ND	ND
03 Dec 96	a.	3.333	ND	ND
	b.	3.529	ND	ND
12 Feb 97	a.	4.286	1284	91.72
	b.	2.400	473	18.92
13 Feb 97	a.	4.000	418	27.87
	b.	2.727	186	8.45
14 Feb 97	a.	1.429	396	9.43
	b.	1.037	157	2.71
17 Feb 97	a.	1.500	589	14.73
	b.	1.176	298	5.84
18 Feb 97	a.	5.455	1678	152.56
	b.	3.750	732	45.75
20 Feb 97	a.	2.308	430	16.54
	b.	1.875	377	11.78
21 Feb 97	a.	1.364	356	8.09
	b.	1.364	414	9.41
24 Feb 97	a.	3.158	334	17.58
	b.	2.500	189	7.88
Detection limits			**100 ng (=0.10ug/l)**	

a,b - two, individual mid-field drain outlets (see Figure 1)
ND - below detection limits.

Table 4. Summary of event data and measured concentrations of isoproturon and diflufenican in drainflow water emanating from Integrated(IFS) production system I (IPU - ½ rate) 1996-1997

Date	Drainflow Rate (l/min)		isoproturon(ng)		diflufenican (ng)	
			concn./l	loading/sec	concn./l	loading/sec
25 Nov 96	a.	1.071	ND	ND	ND	ND
	b.	0.181	ND	ND	ND	ND
03 Dec 96	a.	2.143	ND	ND	ND	ND
	b.	1.304	ND	ND	ND	ND
12 Feb 97	a.	1.277	ND	ND	ND	ND
	b.	0.952	ND	ND	ND	ND
13 Feb 97	a.	2.222	ND	ND	ND	ND
	b.	1.935	ND	ND	ND	ND
14 Feb 97	a.	0.779	ND	ND	ND	ND
	b.	0.500	ND	ND	ND	ND
17 Feb 97	a.	0.674	ND	ND	ND	ND
	b.	0.438	ND	ND	ND	ND
18 Feb 97	a.	2.727	ND	ND	ND	ND
	b.	1.875	ND	ND	ND	ND
20 Feb 97	a.	1.132	ND	ND	ND	ND
	b.	0.732	ND	ND	ND	ND
21 Feb 97	a.	0.732	ND	ND	ND	ND
	b.	0.496	ND	ND	ND	ND
24 Feb 97	a.	1.667	ND	ND	ND	ND
	b.	1.071	ND	ND	ND	ND
Detection limits			**80 ng(=0.08ug/l)**		**20 ng (=0.02ug/l)**	

a,b - two, individual mid-field drain outlets (see Figure 1)
ND - below detection limits.

Table 5. Summary of event data and measured concentrations of isoproturon and diflufenican in drainflow water emanating from Integrated(IFS) production system II (IPU full rate) 1996-1997

Date	Drainflow Rate (l/min)		isoproturon(ng)		diflufenican (ng)	
			concn./l	loading/sec	concn./l	loading/sec
25 Nov 96	a.	0.522	<80	<0.723	ND	ND
	b.	0.316	ND	ND	ND	ND
03 Dec 96	a.	0.343	ND	ND	ND	ND
	b.	0.417	ND	ND	54	0.375
12 Feb 97	a.	1.200	ND	ND	ND	ND
	b.	1.463	80	1.951	ND	ND
13 Feb 97	a.	2.143	ND	ND	ND	ND
	b.	2.069	ND	ND	ND	ND
14 Feb 97	a.	0.667	ND	ND	ND	ND
	b.	0.438	ND	ND	ND	ND
17 Feb 97	a.	0.448	ND	ND	ND	ND
	b.	0.224	ND	ND	ND	ND
18 Feb 97	a.	2.069	ND	ND	ND	ND
	b.	1.765	ND	ND	ND	ND
20 Feb 97	a.	0.789	ND	ND	ND	ND
	b.	0.469	ND	ND	ND	ND
21 Feb 97	a.	0.382	ND	ND	ND	ND
	b.	0.200	ND	ND	ND	ND
24 Feb 97	a.	1.071	ND	ND	ND	ND
	b.	0.594	ND	ND	ND	ND
Detection limits			**80 ng(=0.08ug/l)**		**20 ng (=0.02ug/l)**	

a,b - two, individual mid-field drain outlets (see Figure 1)
ND - below detection limits.

5.3. Nutrient Losses

Although determinations were done for total oxidised nitrogen, virtually all detected could be regarded as nitrate.

5.3.1. Total Oxidised Nitrogen: 1995-1996

On each of the occasions when field drains discharged from both conventional and integrated systems, total oxidised nitrogen concentrations detected in the drain water discharge samples from the integrated field units were significantly lower (63%, 58% and 35% reductions, respectively) than those detected in discharges from the conventional system, with an average overall reduction in loading of 82% (Table 6,7).

5.3.2. Total Oxidised Nitrogen: 1996-1997

Although 160 kgN/ha was applied to the conventional wheat crop (561), 80 kgN/ha to spring oilseed rape (562) and none to spring beans (563) in the 1996 cropping year, post harvest residual soil N values were similar, 80 kgN/ha, 68 kgN/ha and 75 kgN/ha, respectively.

The total oxidised nitrogen concentrations detected in drain water discharges from the conventional system ranged between 22 mgN/l and 41 mgN/l during the sampling period, with an overall average of 33.4 mgN/l (Table 8). Concentrations detected in drainwater discharged from integrated production system I ranged between 10 mgN/l and 15 mgN/l and averaged 12.7 mgN/l over the sampling period (Table 9), whereas those detected in drain water discharged from integrated production II, that received two cultivations prior to drilling, were somewhat higher on the first two occasions when drains ran (range 15mgN/l - 21 mgN/l), and attributed to greater N mineralisation from increased soil disturbance, but thereafter did not exceed 5.3 mgN/l, with an overall average of 6.8 mgN/l (Table 10).

Total oxidised nitrogen loading from the conventional system ranged between 0.39 mgN/second and 3.06 mgN/second and averaged 1.28 mgN/second, whereas loading from both integrated systems ranged between 0.01mgN/second and 0.59 mgN/second with overall averages of 0.25 and 0.08 mgN/second, reductions of 80% and 94%, respectively (Table 10). Comparing the conventional production system with the two integrated production systems showed that on each of the sampling occasions total oxidised nitrogen loading was reduced by at least 80% by the integrated production system and, averaged overall the sampling period, by 87% (Table 10).

5.3.3. Phosphate: 1995-1996

On the first occasion when field drains ran (20 December 1995) greater amounts of soluble phosphate were detected in the drain water discharge samples taken from the field drain discharges of the conventional system (165 ugP/l) than from the integrated production system (46 ugP/l). Thereafter, levels detected were low from both production systems. Average loading of soluble phosphate in the drain outlet discharges was 81% lower from the integrated production system than from the conventional system (Tables 6,7).

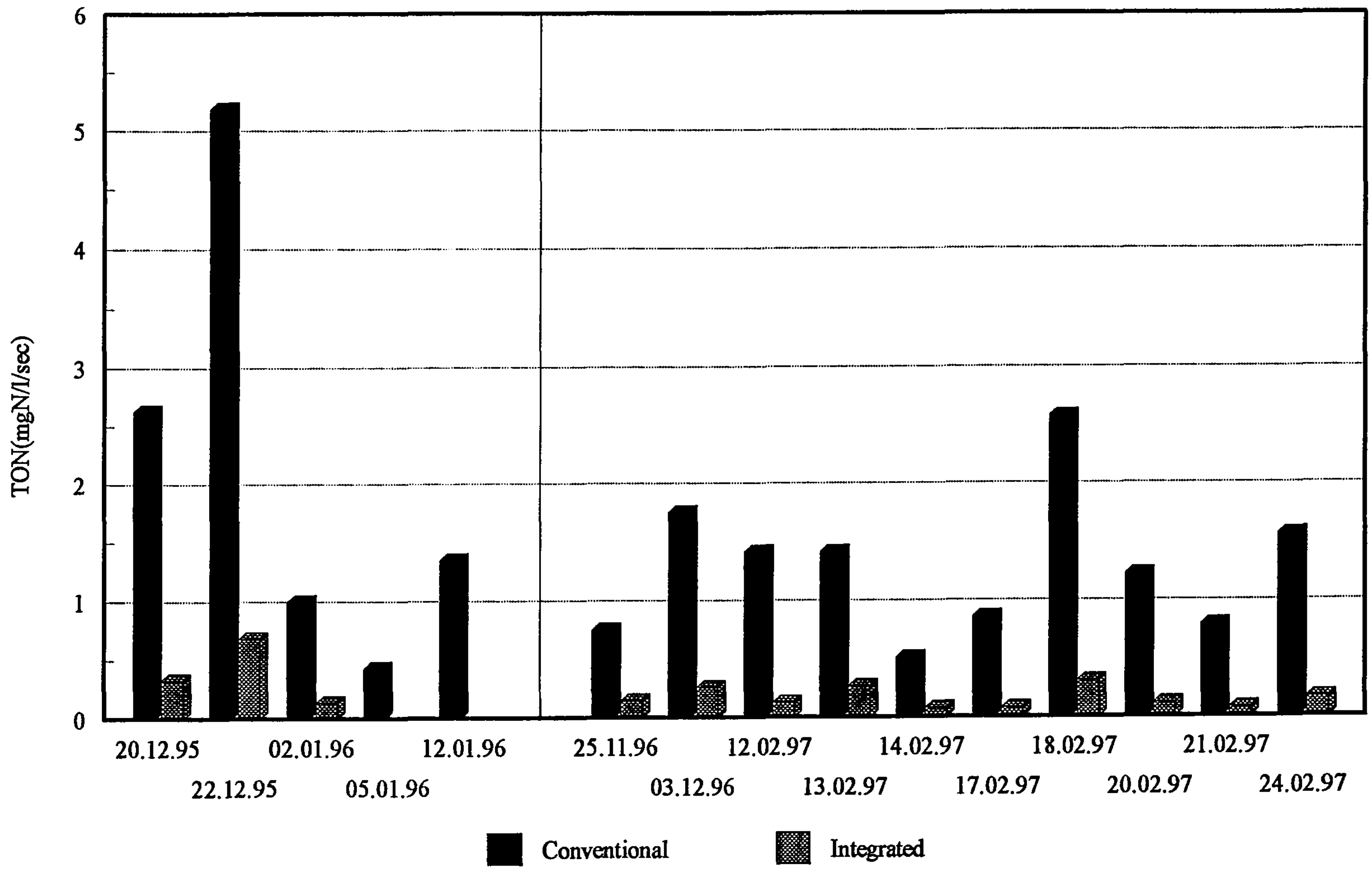

Figure 3. Total oxidised nitrogen (mg) loading/sec in drainwater discharges from conventional and integrated systems 1995-1997.

Table 6. **Summary of event data and measured concentrations of total oxidised nitrogen and phosphate in drainflow water emanating from Conventional(ICM) production systems 1995-1996**

Date	Drainflow Rate (l/min)	Total Oxidised Nitrogen (mg)		Soluble Phosphate (ug)	
		concn./l	loading/sec	concn./l	loading/sec
20 Dec 95	3.375	46.96	2.630	164.97	9.280
22 Dec 95	5.850	53.21	5.190	5.91	0.589
02 Jan 96	1.481	40.60	1.001	3.09	0.076
05 Jan 96	0.632	40.76	0.430	2.31	0.024
12 Jan 96	2.550	31.67	1.346	1.54	0.065
12 Feb 96	Res.sample *	27.60	nf	6.73	nf
Overall Mean	2.776	42.64	2.119	35.56	2.007

* Res.sample - accumulated drainage 01/02 - 12/02/96 (bulk sample); nf=no flow.

Table 7. **Summary of event data and measured concentrations of total oxidised nitrogen and phosphate in drainflow water emanating from Integrated(IFS) production systems 1995-1996**

Date	Drainflow Rate (l/min)	Total Oxidised Nitrogen (mg)		Soluble Phosphate (ug)	
		concn./l	loading/sec	concn./l	loading/sec
20 Dec 95	1.130	17.37	0.327	45.63	0.859
22 Dec 95	1.830	22.16	0.676	9.26	0.282
02 Jan 96	0.310	26.59	0.138	5.59	0.029
05 Jan 96	nf	nf	nf	nf	nf
12 Jan 96	nf	nf	nf	nf	nf
12 Feb 96	Res.sample *	27.60	nf	ND	ND
Overall Mean	1.090	22.04	0.380	20.16	0.390

* Res.sample - accumulated drainage 01/02 - 12/02/96 (bulk sample); nf=no flow.

Table 8. **Summary of event data and measured concentrations of total oxidised nitrogen and phosphate in drainflow water emanating from Conventional(ICM) production systems 1996-1997**

Date	Drainflow Rate (l/min)		Total Oxidised Nitrogen (mg)		Soluble Phosphate (ug)	
			concn./l	loading/sec	concn./l	loading/sec
25 Nov 96	a.	0.932	33.83	0.525	23.29	0.362
	b.	1.818	32.45	0.983	10.81	0.328
03 Dec 96	a.	3.333	31.88	1.771	54.12	3.006
	b.	3.529	29.43	1.731	14.96	0.880
12 Feb 97	a.	4.286	26.80	1.914	31.26	2.233
	b.	2.400	22.41	0.896	18.80	0.752
13 Feb 97	a.	4.000	26.62	1.775	15.28	1.019
	b.	2.727	22.77	1.035	9.24	0.420
14 Feb 97	a.	1.429	26.46	0.630	10.89	0.158
	b.	1.037	22.57	0.390	7.30	0.126
17 Feb 97	a.	1.500	40.74	1.109	11.44	0.286
	b.	1.176	35.69	0.700	7.34	0.144
18 Feb 97	a.	5.455	33.70	3.064	15.51	1.410
	b.	3.750	33.50	2.094	6.97	0.436
20 Feb 97	a.	2.308	36.14	1.390	8.43	0.324
	b.	1.875	33.26	1.039	7.02	0.219
21 Feb 97	a.	1.364	36.34	0.826	11.29	0.257
	b.	1.364	33.10	0.752	7.41	0.168
24 Feb 97	a.	3.158	34.20	1.800	11.03	0.581
	b.	2.500	31.72	1.322	30.71	1.280
Overall Mean		2.497	33.40	1.283	15.66	0.720

a,b - two, individual mid-field drain outlets (see Figure 1)

Table 9. **Summary of event data and measured concentrations of total oxidised nitrogen and phosphate in drainflow water emanating from Integrated(IFS) production system I: 1996-1997**

Date	Drainflow Rate (l/min)		Total Oxidised Nitrogen (mg)		Soluble Phosphate (ug)	
			concn./l	loading/sec	concn./l	loading/sec
25 Nov 96	a.	1.071	15.54	0.275	44.87	0.801
	b.	0.181	14.23	0.043	16.17	0.049
03 Dec 96	a.	2.143	14.47	0.517	8.85	0.316
	b.	1.304	13.06	0.284	23.38	0.517
12 Feb 97	a.	1.277	11.28	0.240	15.66	0.333
	b.	0.952	10.22	0.162	17.91	0.284
13 Feb 97	a.	2.222	11.40	0.422	5.60	0.207
	b.	1.935	10.79	0.348	8.25	0.266
14 Feb 97	a.	0.779	10.46	0.136	6.45	0.084
	b.	0.500	10.44	0.087	7.94	0.066
17 Feb 97	a.	0.674	15.01	0.169	8.48	0.095
	b.	0.438	14.23	0.104	6.71	0.049
18 Feb 97	a.	2.727	12.93	0.588	12.63	0.574
	b.	1.875	13.12	0.410	7.87	0.246
20 Feb 97	a.	1.132	12.86	0.245	6.96	0.131
	b.	0.732	12.79	0.156	5.84	0.071
21 Feb 97	a.	0.732	13.05	0.159	*58.74	0.716
	b.	0.496	12.87	0.106	10.00	0.083
24 Feb 97	a.	1.667	12.52	0.348	12.54	0.348
	b.	1.071	12.57	0.224	*32.87	0.587
Overall Mean		1.195	12.69	0.251	15.87	0.295

a,b - two, individual mid-field drain outlets (see Figure 1)
* unexplainable value

Table 10. **Summary of event data and measured concentrations of total oxidised nitrogen and phosphate in drainflow water emanating from Integrated(IFS) production system II: 1996-1997**

Date	Drainflow Rate (l/min)		Total Oxidised Nitrogen (mg)		Soluble Phosphate (ug)	
			concn./l	loading/sec	concn./l	loading/sec
25 Nov 96	a.	0.522	21.05	0.183	15.49	0.135
	b.	0.316	19.76	0.104	11.88	0.063
03 Dec 96	a.	0.343	19.26	0.110	*80.57	0.461
	b.	0.417	15.52	0.108	16.58	0.115
12 Feb 97	a.	1.200	3.43	0.069	17.54	0.351
	b.	1.463	2.35	0.057	15.10	0.368
13 Feb 97	a.	2.143	4.48	0.169	5.78	0.206
	b.	2.069	3.86	0.133	6.83	0.236
14 Feb 97	a.	0.667	4.80	0.053	6.17	0.069
	b.	0.438	4.41	0.032	6.84	0.050
17 Feb 97	a.	0.448	5.32	0.040	6.76	0.050
	b.	0.224	3.24	0.012	5.74	0.021
18 Feb 97	a.	2.069	3.97	0.137	7.41	0.255
	b.	1.765	3.52	0.104	11.00	0.324
20 Feb 97	a.	0.789	3.75	0.049	6.14	0.081
	b.	0.469	3.40	0.027	7.35	0.057
21 Feb 97	a.	0.382	3.84	0.024	7.75	0.049
	b.	0.200	3.25	0.011	7.19	0.024
24 Feb 97	a.	1.071	3.14	0.056	8.51	0.152
	b.	0.594	3.14	0.031	13.66	0.135
Overall Mean		0.879	6.77	0.075	13.21	0.160

a,b - two, individual mid-field drain outlets (see Figure 1)
* unexplainable value

Table 11. **Summary of event data and Total Oxidised Nitrogen loading in drainflow water emanating from the LIFE Systems Comparisons 1996-1997**

Date	Total Oxidised Nitrogen (mg) - loading/second			
	Conventional	Integrated I	Integrated II	Difference(%)*
25 Nov 96	0.754	0.159	0.144	-80%
03 Dec 96	1.751	0.401	0.109	-85%
12 Feb 97	1.405	0.201	0.063	-91%
13 Feb 97	1.405	0.385	0.147	-81%
14 Feb 97	0.510	0.112	0.043	-85%
17 Feb 97	0.860	0.137	0.026	-91%
18 Feb 97	2.579	0.499	0.121	-88%
20 Feb 97	1.215	0.200	0.038	-90%
21 Feb 97	0.789	0.133	0.018	-90%
24 Feb 97	1.561	0.286	0.044	-89%
Overall Mean	1.283	0.251	0.075	-87%
Reduction(%)		80.44	94.16	

* Difference between Conventional and mean Integrated I + II values

Table 12. Summary of event data and soluble phosphate emissions in drainflow water emanating from the LIFE Systems Comparisons 1996-1997

Date	Soluble Phosphate (ug) - loading/second			
	Conventional	Integrated I	Integrated II	Difference(%)*
25 Nov 96	0.345	0.425	0.099	-26%
03 Dec 96	1.943	0.457	0.288	-81%
12 Feb 97	1.493	0.309	0.360	-88%
13 Feb 97	0.720	0.237	0.221	-67%
14 Feb 97	0.142	0.075	0.060	-52%
17 Feb 97	0.215	0.072	0.036	-75%
18 Feb 97	0.923	0.410	0.290	-62%
20 Feb 97	0.272	0.101	0.069	-69%
21 Feb 97	0.213	♦0.400	0.037	♦+ 2%
24 Feb 97	0.931	0.468	0.144	-67%
Overall Mean	0.720	0.295	0.160	-68%
Reduction(%)		59.03	77.78	

* Difference between Conventional and mean Integrated I + II values

♦ unexplainable value

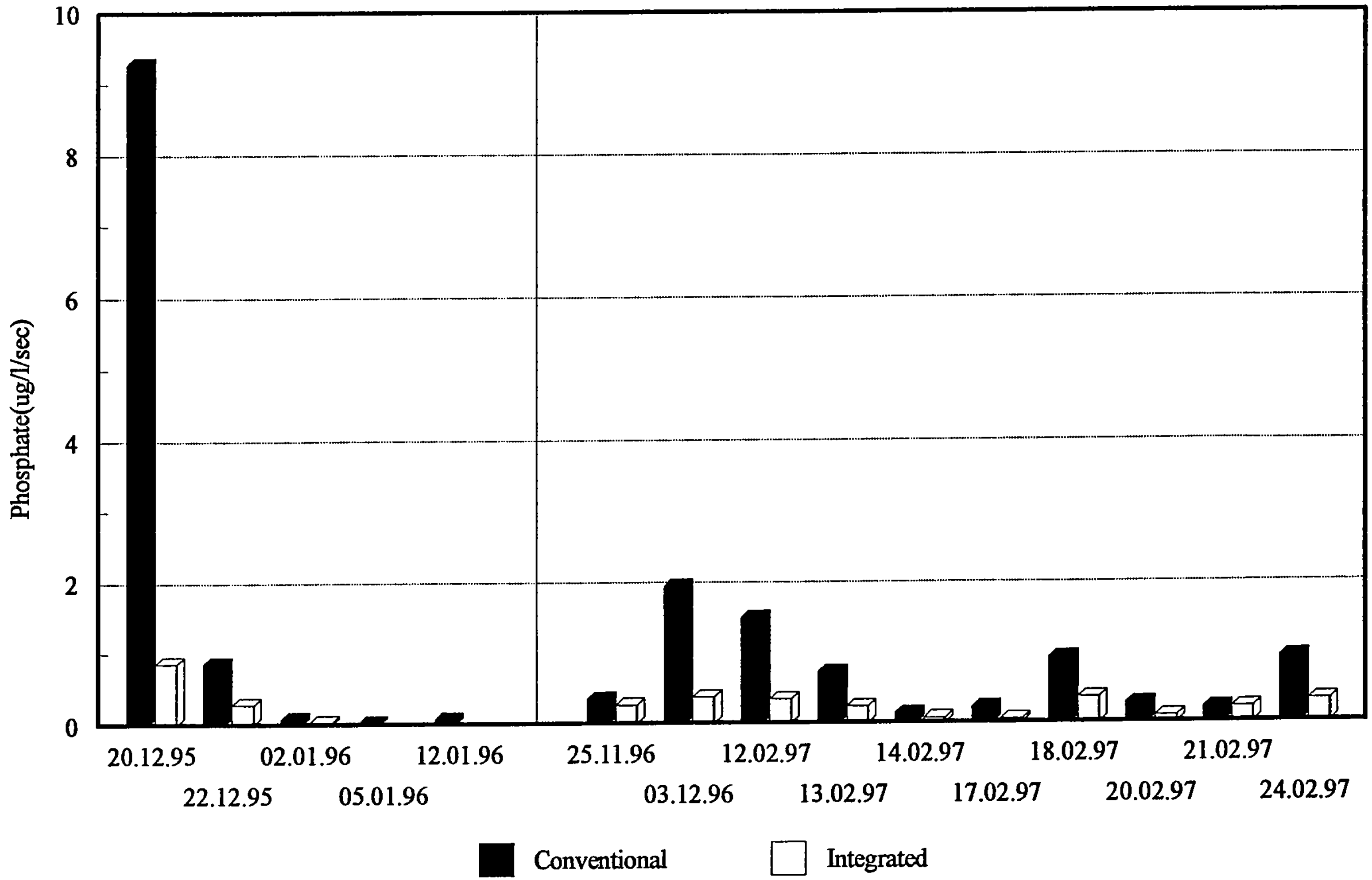

Figure 4. Soluble phosphate(ug) loading/sec in drainwater discharges from conventional and integrated systems 1995-1997.

5.3.4. Phosphate: 1996-1997

The soluble phosphate concentrations detected in drain water discharges from the conventional system were variable and ranged between 7 ugP/l and 54 ugP/l during the sampling period, with an overall average of 15.7 ugP/l (Table 8). Concentrations detected in drainwater discharged from integrated production system I ranged between 6 ugP/l and 45 ugP/l and averaged 15.9 ugP/l over the sampling period (Table 9), whereas those detected in drain water discharged from integrated production II ranged between 6 ugP/l and 18 ugP/l, with an overall average of 13.2 ugP/l (Table 10).

Total phosphate loading from the conventional system ranged between 0.13 ugP/second and 3.00 ugP/second and averaged 0.72 ugP/second, whereas loading from both integrated systems ranged between 0.02 ugP/second and 0.80 ugP/second with overall averages of 0.3 and 0.16 ugP/second, reductions of 59% and 78%, respectively. Comparing the conventional production system with the two integrated production systems showed that on the first occasion field drains ran phosphate loading was only reduced by 26%, but thereafter, and with the exception of an unexplained value in one of the drain samples on 21 February, reductions were in excess of 52% in the integrated production system and, averaged overall the sampling period, by 68% (Table 12).

Comparative loadings for total oxidised nitrogen and soluble phosphate in drainwater discharges from conventional and integrated production fields on each occasion field drains ran between 20 December 1995 and 24 February 1997 are given, diagramatically, in Figures 3 and 4 respectively.

A direct comparison of loadings at this site is seen as legitimate, as the Field Units are of equal size and design.

6. DISCUSSION

Common farm practice in conventional arable crop production is to apply a routine autumn herbicide programme reliant upon isoproturon, for grass and broad leaf weed control in cereals, with less intensive herbicide use in the spring. However, the policy for integrated production is generally to avoid using leachable products in the autumn, and direct the strategies towards contact herbicides which have a lower emission potential and are spring-applied. However, if weed risk determinations indicate that isoproturon is required, then it is applied at an appropriate (reduced) rate.

Despite the somewhat climatically-determined limited frequency of drainwater discharge sampling during the first year (1995/96), the data from the experimental fields over the two years (1995-1997) provides some clear indication that the integrated production system substantially reduces emissions of total oxidised nitrogen and phosphate from drainwater outflows compared with conventional production systems. Furthermore, in both sampling years, isoproturon levels did not exceed detection limits in any drain water discharged from

the integrated field units that received the reduced IFS field rate (½ rate) application of isoproturon, and was only detected on one occasion (0.08 ug/l) in drainflow from an integrated production field that received the recommended rate of application.
On the occasions when all drains flowed, the average total oxidised nitrogen emissions from the integrated production system were reduced by, on average, 80%, and phosphate emissions by 65% compared with the conventional system. This effect, supported by data from a supplementary component study (Brown et al, 1996) was mainly attributed to soil conservation tillage practices (non-inversion tillage) in the integrated system. It should be noted, however, that non-inversion tillage has been adopted in the integrated field units of the LIFE Project during the previous six years and, as a consequence, markedly affected soil physical, chemical and biological parameters, especially soil structure.

Different soil tillage systems influence several physical, microbiological and chemical soil parameters, which have implications for the fate, degradation and translocation of organic herbicides. Recent research (Düring & Hummel, 1993) revealed that isoproturon tends to degrade faster under soil conservation tillage systems than under traditional ploughed land. Of the processes involved, fixation leading to "bound residues" which remain invisible under classical analysis is one component, with the intensity of degradation through microbial activity and leaching (translocation) greatly influenced by the soil properties.
Up to 90% of isoproturon is expected to be degraded within the first two months from application, with an accelerated degradation in soil from conservation tillage systems than from soil that has been ploughed. This response is mainly attributed to increased microbial activity. High absorption through high organic content of soils utilising non-inversion tillage leads to accelerated degradation. The increased microbial activity in soil conservation tillage systems than in conventionall ploughed soils favours the degradation pathway of isoproturon → the metabolite monomethyl-isoproturon, rather than total mineralisation with production of CO_2 (Otto et al) and, thus, disappearance of monomethyl-isoproturon is faster in minimum tillage systems, thereby reducing its susceptibility to leaching.

The quantity of herbicide that can be intercepted by crop residues is of particular importance, as it is withheld from the soil especially if there is no rainfall events capable of returning it into the soil (Gaynor et al., 1995); a fraction is also intercepted by the crop canopy and "wash-off" is only possible in rain immediately following application. In general, all herbicides and metabolites tend to localise in the top 10 cm soil layer and, hence, adsorption plays an important role.

The aforementioned processes and interactive elements are considered to be the main functional components that help explain the minimal emissions of isoproturon from integrated systems compared with conventional systems of production that are established following the traditional plough and subsequent cultivations.

Non-inversion tillage, therefore, appears to offer substantial improvements in minimisation of herbicide and nutrient emissions and, hence, diffuse pollution from arable crop land. On the basis of the data generated from this study, strategies for protection of water quality should, therefore, consider implementation of soil conservation tillage systems in high risk areas (land adjoining water courses) or, possibly, within whole catchments.

7. RECOMMENDATION FOR FURTHER STUDY

Whilst this study has demonstrated reductions in herbicide and nutrient emissions in drainwater discharges from fields managed according to the guidelines for integrated production (El Titi et al., 1993) it did not provide information on the fate of herbicides and nutrients within the soil. Such studies within the soil profile could provide more conclusive evidence concerning the influence of different soil management systems on the time course, spacial distribution, degradation and emissions of herbicides and nutrients, and their implications for protection of water quality. Whilst it may be scientifically advantageous to adopt soil conservation tillage for waste minimisation, there is still commercial reluctance to implementation. However, it is not yet known whether similar responses could be obtained after just one year of non-inversion tillage or whether these effects only develop over time, or indeed, whether whole-field or field boundary implementation is required to obtain the required responses. One possible option would be to adopt this practice, initially, along the boundaries of fields (2-4 drill widths) adjacent to controlled waters. This type of study would not only address the cropland-width requirement but also allow the practitioner to obtain comparable experience of conventional and integrated approaches within-farm.

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Appendix 1. LIFE Field 56 - Crop Management: 1994 - 1995 Cropping Year

FIELD UNIT/SYSTEM	561 / SFP	562 / IFS	563 / IFS	564 /IFS
INPUT/CROP- 1995	OILSEED RAPE	WINTER WHEAT	WINTER WHEAT	SPRING BEANS
Cultivation Variety/sown	Plough Apex: 17/8/94	Incorporate Genesis: 3/10/94	Incorporate Spark: 3/10/94	Incorporate Victor: 25/3/95
Basal Fertiliser	75P+75K: 7/4/95	49P+49K: 14/3/95 50P: 21/4/95	85P+85K: 14/3/95	49P+49K: 25/3/95
Nitrogen	80N: 10/3/95 80N: 9/4/95	101N: 21/4/95 15N: 26/5/95	100N: 23/4/95 15+16N: 26/5 + 9/6/95	
Herbicides	propyzamide: 720g 1/10/94 cycloxidim: 200g 6/4/95	metsulfuron: 3g bromox/ioxynil: 85/85g fenoxaprop: 24g fluroxpyr: 100g 4/4 + 18/5/95	metsulfuron: 2g 14/3/95 (Harrow x3)	propaquizafop: 150g 22/5/95
Fungicides	vinclozolin: 500g	propiconazol: 125g tridemorph: 330g	tebuconazole: 188g triadimenol: 94g	
Insecticides	cypermethrin: 20g	cypermethrin: 10g pirimicarb: 75g	pirimicarb: 70g	
Dessicant	glyphosate: 1080g			glyphosate: 1080g
Yield	1.84t/ha	8.62t/ha	8.10t/ha	3.14t/ha
Variable Costs	£ 324.27	£ 196.61	£ 156.18	£ 224.08
Gross Margin	£ 526.00	£1049.20	£1030.72	£ 566.95

Appendix 2. LIFE Field 56 : Crop Management: 1995 - 1996 Cropping year.

FIELD UNIT/SYSTEM	561 / SFP	562 / IFS	563 / IFS	564 / IFS
INPUT/CROP- 1996	WINTER WHEAT	SPRING OS RAPE	SPRING BEANS	WINTER WHEAT
Cultivation Variety/sown	Simba + Plough Hereward: 28/9/95	Dynadrive: 9/10/95 Spok: 29/3/96	Dynadrive: 9/10/95 Victor: 29/3/96	Simba + Dutzi Spark: 9/10/95
Herbicide:	isoproturon: 1875g diflufenican: 75g **1/11/95**	glyphosate: 720g **28/9/95**	glyphosate: 240g **28/9/95**	isoproturon: 750g diflufenican: 25g **1/11/95**
OUTFLOW FROM FIELD DRAINS BEGAN 28/11/95 - FIRST SAMPLE TAKEN ***The following crop management inputs were applied after drainflow sampling ceased***				
Nutrients	71P +71K: 40N + 11S: 79N: 39N + 25K.	79N + 20S.		71P +71K:40N + 11S: 79N: 32N
Agrochemicals/ Crop Protection	cypermethrin: 20g chlormequat: 1120g epoxiconazole: 125g fluroxypyr: 200g propiconazole: 125g tridemorph: 375g chlorothalonil: 500g chlorpyrifos 400g	Harrow (15/5)	Harrow (15/5)	metsulfuronmethyl: 4g (27/4) fluroxypyr: 200g tebuconazole: 188g
Yield	10.05t/ha	1.63 t/ha	3.77 t/ha	8.05 t/ha
Variable Costs#	£278.80	£120.67	£110.29	£206.82
Gross Margin	£1174.91	£665.82	£758.89	£872.29

does not include operational costs

Appendix 3. LIFE Field 56 : Crop Management: 1996 - 1997 Cropping year.

FIELD UNIT/SYSTEM	561 / SFP	562 / IFS	563 / IFS	564 / IFS
INPUT/CROP- 1997	WINTER BEANS	WINTER WHEAT	WINTER WHEAT	WINTER OATS
Cultivation Variety/sown Basal Fertiliser	Plough: Springtine(x2) Punch: 14/11/96 30P + 30K 10/09/96	Dutzi: 09/10/95 Genesis: 23/10/96	Dynadrive: 10/09/96 Reaper: 02/10/96	Dynadrive: 02/10/96 Krypton: 12/10/96
Herbicide:	simazine: 750g **21/01/97**	glyphosate: 720g **02/10/96** isoproturon: 1000g diflufenican: 25g **06/12/96**	isoproturon: 2000g diflufenican: 25g **06/12/96**	NIL
OUTFLOW FROM FIELD DRAINS BEGAN 25/11/95 - FIRST SAMPLE TAKEN ***The following crop management inputs were applied after drainflow sampling ceased - 24 February 1997***				
Nutrients	***EXTENSIVE CROP DAMAGE (Crows)***	42P+58K+110N 16/04/97	42P+58K+110N 16/04/97	30P+30K 28/03/97 19P+26K+50N 29/04/97
Agrochemicals/ Crop Protection	***Field Unit re-sown with Spring Beans (cv Maris Bead) 28/03/97***	Harrow 28/03/97 01/04/97 18/04/97	metsulfuron-methyl 3g 29/03/97 amidosulfuron 15g 04/04/97	metsulfuron-methyl 3g 29/03/97 amidosulfuron 15g 04/04/97
Yield	3.99t/ha	7.68t/ha	7.95t/ha	5.44t/ha
Variable Costs#	£217.79	£222.57	£231.68	£156.13
Gross Margin	£736.32	£669.04	£682.23	£778.23