COMPARISON OF CEREALS GROWN UNDER HIGH (CONVENTIONAL) AND LOW (REDUCED) INPUTS SYSTEMS

Authors

M.J. Conry and J.J. Hogan
Crops Research Centre,
Oak Park, Carlow

With contributions from B. Dunne, T. Kennedy and B. Mitchell, Crops Research Centre, Oak Park, Carlow

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SUMMARY

This long-term experiment, which commenced at Oak Park in September 1994, compared the effect of a high inputs system with a low inputs system on the yield and quality of winter wheat and winter barley grown

(i) In a non-cereal break-crop rotation with spring barley
(ii) In a continuous cereal break-crop rotation with winter oats, and
(iii) Continuous cereals.

The experimental site at Knockbeg consisted of a medium-heavy textured, free-draining grey-brown podzolic soil (Knockbeg Series).

The objective of the experiment was to measure the effect of reduced inputs on grain yield, grain quality, production costs and the profitability of the important cereal crops grown in different rotations, so that the impact of a more environmentally-friendly inputs system could be assessed and compared with conventional production systems.

The inputs in the conventional (high) system were consistent with good farm practices carried out by the best cereal growers, while in the low inputs system the amounts of agro-chemicals used were decision-based using specified principles. The level of N applied was reduced by 37.5 kg/ha (30 units/ac) for winter cereals and by 32.5 kg/ha (26 units/ac) for spring malting barley in the low inputs system. P was not applied to the cereals grown in the low inputs system due to the very high levels of residual phosphorus (P) in the soil. On principle, the low inputs system was treated with a maximum of half the rate (or less) of crop protection chemicals applied to the high system to control BYDV, weeds, lodging, foliar, stem and root diseases.

There was little change in soil pH or potassium levels over the 5-year period (1994-99), but the P levels decreased considerably in both the high and low inputs systems. Despite the application of the recommended rate of P to the high inputs system, the level of residual P in the soil decreased from 19.5 mg/l in 1994 to 15 mg/l in 1999. On the other hand, the level of P decreased from a mean value of 18 mg/l in 1994 to 10 mg/l in 1999 in the low inputs system, which received no phosphorus throughout the 5-year period.

Over the four-year period, 1996-99, winter wheat gave the greatest yields, followed by winter barley and winter oats. Lodging reduced winter wheat and winter oats yields substantially in 1998. The low yields of spring malting barley, also in 1998, have been attributed to severe leaf spotting disorder on the variety Cooper and possibly to leaching of nitrogen.

All cereal crops, grown under the conventional (high) system, gave greater yields than the low inputs system in all years. However, the winter cereal crops gave greater financial returns when grown under the low inputs system. On the other hand, spring malting barley gave higher gross margins in the high system. The costs of producing a tonne of winter cereals was generally £10 lower in the low inputs system, but the margin was much smaller in the case of spring malting barley. The costs of producing a tonne of grain (unit production costs) were very dependent on grain yield, which was largely controlled by seasonal factors.

INTRODUCTION

An experiment to compare cereal inputs systems was initiated in 1994 against the changing background in agriculture in general, and tillage crops in particular, over the last few decades. In the 1970’s and early 1980’s, with few constraints on agricultural production, the emphasis was placed on high input and high output systems. With high prices for cereals, together with increasing prices, this gave optimum profits to the efficient cereal producer.

However, towards the end of the 1980s, the ever-increasing grain surplus in the EU and the threat of reduced prices, placed special emphasis on reducing costs so that the profitability of cereal growing and the viability of the grain industry could be maintained. At the same time, there were growing concerns of the possible detrimental effects of the intensive use of agro-chemicals on the environment, together with a greater awareness of the necessity to produce high-quality, safe food.

The increased emphasis on the production of quality food, in an environmentally-friendly way, increased the need for information on the impact of reduced inputs on grain yields, grain quality, unit costs and the profitability of the various cereal enterprises grown in different rotations, when compared with one another and with other farm enterprises.

METHODS

Experimental design

This long-term experiment, which was commenced in September 1994, compared the effects of (i) a conventional (high) inputs system and (ii) a decision-based reduced (low) inputs system on the yield, quality and profitability of the principal cereal crops (winter wheat, winter barley, winter oats and spring malting barley) grown in different rotations (Table 1) as well as continuous winter wheat and winter barley. To eliminate the effects of seasonal factors on crop rotations, all the crops in the rotation were sown and harvested each year.

Table 1: Cropping rotations (1996-99)

(a) Non cereal break-crop	(b) Cereal break-crop
Winter beans	Winter Wheat
Winter wheat	Winter barley
Spring malting barley	Winter oats
Winter oil-seed rape	
Winter barley	

The inputs in the conventional system were consistent with good farm practices carried out by the best cereal growers, while the inputs in the reduced inputs system were decision-based on value judgements and certain principles.

Plot size (30 m x 12.5 m) was large by experimental standards, to aid mechanisation of crop treatments and to eliminate the possible disadvantages associated with small plots. The experiment, is of necessity long-term because more than one rotation cycle is essential to fully assess the impact of crop rotations. Each year, however, the impact of the conventional and reduced inputs systems on the various cereal crops can be assessed.

Experimental site

The experiment was located on the Knockbeg farm in the Wood Field No. 2, which consists of a deep (>1 metre), free-draining grey-brown podzolic soil derived from limestone boulder clay (Knockbeg Series). The clay loam to loamy surface A horizon, which has a weak structure, overlies a heavy-textured well-structured textural B horizon with a high clay content (40-45% clay and 35% silt).

The soil has a high moisture capacity. Although soil moisture deficits may occur, crops seldom show any drought symptoms.

Crop inputs

The variety sown was generally selected on the basis of its high yield and quality of the grain. The high-yielding variety Brigadier was grown in all four years in the conventional system, while variety Ritmo, with its greater resistance to leaf diseases, was selected for the reduced inputs system. The winter barley variety Intro was grown in both conventional and reduced inputs systems in 1996, but it was replaced by the higher-yielding variety Regina, which was also less prone to lodging, in the three years, 1997-99. Although the winter oat variety Barra was not the highest yielding cultivar available, it was chosen because its greater acceptability to the millers due to its relatively higher hectolitre weight. The spring malting barley variety Cooper was grown in all four years of the experiment (1996-99).

All cereal crops were sown early, consistent with good husbandry practices, at the same seed rate for both conventional and reduced inputs systems in good soil conditions. Winter barley was sown in the second half of September (circa 23 September), while winter wheat and winter oats were sown in the last few days of September or very early October (before 8 October). The spring barley was sown between January and early March depending on soil conditions.

The amounts of NPK applied in the conventional system were consistent with good farm practices carried out by intensive cereal growers (Table 2). The amount of N applied to the reduced system was 37.5 kg/ha (30 units/ac) lower than on the conventional system for the three winter cereals, wheat, oats and barley. The amount of N applied to the winter wheat (both systems) was reduced by 25 kg/ha (20 units/ac) when grown after the break-crop (beans). In the case of spring malting barley, the conventional system received 137.5 kg N/ha, which was considered the amount required on that soil type, to produce the optimum yield of acceptable quality malting barley. The reduced inputs system was given 105 kg N/ha (26 units/ac less), the maximum allowed under REPS.

The conventional and reduced systems were given the same quantities of potassium, because K levels in the soil were low to medium, but no phosphorus was applied to the reduced inputs system because of the excessively high P levels (18 mg/l+) in the soil.

Table 2: Nitrogen, phosphorus and potassium application rates (1996-99)

Crop	Inputs system	Nitrogen (kg/ha)	P & K (kg/ha)
Winter wheat	High	225	432 (0.7.30 NPK)
	Low	187.5	222 (KCl)*
Winter barley	High	187.5	371 (0.7/30 NPK)
	Low	150	222 (KCl)
Winter oats	High	137.5	371 (0.7.30 NPK)
	Low	100	222 (KCl)
Spring barley	High	137.5	432 (18.6.12 NPK)
	Low	105	519 (20.0.15 NPK)

*Muriate of potash

Pesticides were applied at recommended rates, consistent with good farm practices, to the conventional (high) inputs systems to control BYDV, weeds, foliar and root diseases and lodging. It was decided, on principle, that the reduced inputs system would be given a maximum of half the label-recommended rate (or less) of the pesticides applied to the conventional system. The early-sown conventionally-grown winter cereals were generally given two contact insecticides, to control BYDV - the first in mid-October at the 2-leaf stage and the second in early November - while the reduced inputs system received one application in early November. The malting barley was sown early and, therefore, no insecticide was applied in any of the four years. Weeds were controlled in the conventional inputs winter wheat and barley with a full label-recommended dose of Cougar (diflufenican/IPU) at G.S. 25, while the reduced system received half the rate at the same time in the autumn (Table 3).

Table 3: Herbicide programme to control weeds (1996-99)

Cereal	Inputs system	
	High	Low
Winter wheat (Cereal break-crop and Continuous)	Cougar (1.5L/HA)	Cougar (0.75 L/HA)
Winter Wheat (Non cereal Break-crop)	Cougar (1.5 L/HA) plus Duplosan (1.4 L/HA)	Cougar (0.75 L/HA) plus Duplosan (1.4 L/HA)
Winter barley	Cougar (1.5 L/HA)	Cougar (0.75 L/HA)
Winter oats	Ally (30g/ha) plus Starane (0.75 l/ha)	Ally (15g/ha) plus* Starane (0.375 l/ha)
Spring barley	Bandit**(5.6 L.HA)	Bandit (2.8 L/HA)

* None in 1998
** Bandit contains dicamba, MCPA, CMPP

Weeds were controlled in the winter oats by applying the appropriate herbicide, either in the autumn or the spring. The reduced system received half the amount of herbicide that was applied to the conventional system except in 1998 when the reduced system received no herbicide due to the low infestation of weeds. A dicamba/CMPP based herbicide was applied in the spring at full and half rates to the spring-sown malting barley at G.S. 20/25.

Growth regulators were applied at the appropriate growth stages to prevent lodging of the winter cereal crops. However, lodging was so severe on the winter wheat and winter oats in 1998, both on the high and reduced inputs system, that it was decided to increase the amount of growth regulator on both winter wheat and oats in 1999 (Table 4).

Table 4: Growth regulators applied to the various cereal crops (1996-99)

Year	Cereal crop	Inputs	
		High	Low
1996-98	Winter wheat	CCC, Moddus or Meteor (full-rate)	CCC, Moddus or Meteor (half-rate)
	Winter barley	Cerone or Moddus (full-rate)	Cerone or Moddus (half-rate)
	Winter oats	CCC (full-rate)	CCC (half-rate)
	Spring barley	None	None
1999	Winter wheat	Meteor (GS 31) (full-rate) + Cerone (0.5 l/ha) (GS 37)	Meteor (GS 31) (full-rate)
	Winter barley	Cerone (full-rate)	Cerone (half-rate)
	Winter oats	CCC (full-rate) + Li700	CCC (full-rate) + Li700
1996-99	Spring barley	None	None

Three full dose broad spectrum fungicides at G.S. 31-32, 39 and 59 were applied to the high input winter wheat crop, while the reduced inputs system was given approximately half that amount. Two full rate fungicides were applied to the winter oats and winter barley at the appropriate crop growth stages, while the reduced systems were given half the amount applied to the conventional (high) system. Table 4 gives details of the fungicide programme carried out in 1999 to control foliar stem and root diseases. Aphid control on plant ears (high inputs system only) was based on aphid counts.

Table 5: Details of fungicide programme to control foliar and root diseases (1999)

Cereal		Inputs	
		High	Low
Winter wheat (cereal break-crop and continuous)	T1	Allegro (full-rate) (GS 31)	Allegro (0.5 l/ha) (Full-rate if eyespot test is high at G.S. 37)
Winter wheat (Non cereal break crop)	T1	Allegro (0.5 l/ha) (Irrespective of Eyespot test at GS 31)	Allegro (0.5 l/ha)
	T2	Opus (0.3 l/ha) + Amistar (0.7 l/ha) (G.S. 37-39)	Allegro (0.5 l/ha) (G.S. 45)
	T3	Amistar (0.8 l/ha) (G.S. 55)	Amistar (0.5 l/ha) (G.S. 55)
Winter barley	T1	Stereo (1.6 l/ha)	Stereo (0.8 l/ha)
	T2	Allegro (1 l/ha)	Allegro (0.5 l/ha)
Winter oats	T1	Fortress Duo (full-rate)	Fortress Duo (half rate)
	T2	Folicur (1 l/ha) + Allegro (0.5 l/ha)	Folicur (half-rate) + Allegro (0.25 l/ha)*
Spring barley	T1	Allegro (0/75 l/ha) (at tillering)	Fortress Duo (0.4 l/ha) (half-rate)
	T2	Allegro (0.75 l/ha)	Allegro (0.4 l/ha) (half-rate)

* Add morpholine if mildew present

Field assessments

Plant populations, fertile tillers, green leaf area, lodging, and grains per ear were determined over the growing season. Plant populations (plants/m^2) and fertile tillers, for both winter and spring cereals, were measured in the same two 0.25 m^2 quadrants per plot. The percentage of green leaf on the top three leaves of all cereal plots was assessed on ten randomly selected plants per plot, generally within three weeks of the last fungicide application. Lodging and brackling were assessed prior to harvesting, using the method of Caldicott and Nuttall (1979). Grains per ear were measured prior to harvesting by counting the number of grains in 20-25 ears per plot.

Foliar, stem and root disease assessments

The amount of diseased tissue, i.e. per cent necrosis, due to the major foliar diseases, was assessed visually, approximately three weeks after applying the final fungicide, on all cereal crops on the top three leaves of 10 randomly selected plants per plot.

The amount of eyespot (*Tapesia* spp.) and take-all (*Gaeumannomyces graminis* var. *tritici*) on winter wheat, winter barley and spring barley, were assessed in the laboratory. In each instance six plants were randomly selected from 25 cm rows of plants (and roots) per plot. Samples were taken 2-3 weeks after earing was completed.

Weed assessments

Weed control assessments were recorded one week before and four to six weeks after herbicide application, in autumn and spring and again before harvesting to assess the efficacy of weed control measures. Weed assessments were expressed on a score of 0 (no control) to 10 (total weed control).

Field fauna assessments

The effect of pesticide applications on selected field fauna was measured in winter wheat grown after a non cereal break-crop (faba beans) and after winter oats in both the conventional (high) and reduced inputs systems, in 1998 and 1999.

Pitfall traps were used to capture ground beetles (*Carabidae*), rove beetles (*Staphylinidae*), spiders (*Araneae*) and slugs (*Mollusca*). Two traps were used per plot. Each was positioned 2.1m from the edge and 15m from the end of the plots. Trapping was carried out over a 7-week period from 25 June to 13 August 1998 and for an 8-week period from 21 June to 17 August in 1999.

Earthworms were collected from two sampling areas per plot, each 0.5 x 0.5 m and within 0.5 m of pitfall trap positions in August 1998 and 1999. Earthworms were collected (formalin method), counted and their fresh weight recorded.

The number of aphids per ear in the high- and low-input wheat plots in the two rotations were counted in June and July 1999. Aphids were again counted on the low-input plots in the second half of July.

Grain and straw yields

Plots were harvested with a plot combine harvester and grain yields were assessed by weighing the grain from two full-length cuts, 30 m long and 2.75 m wide, in each plot - one each side of the tramlines. Straw yield was obtained by weighing the round bales of straw collected on each plot. The beans and oilseed rape were harvested with the same plot harvester, but the crop residue was ploughed back into the soil, due to the extreme difficulty in removing the residue.

Laboratory analysis

Thousand-grain weight, hectolitre weight and screenings were determined on fresh samples. Percentage screenings was assessed on undried samples by passing over a 2.2 mm slotted screen on a Miag grader for 2 minutes. The 1000-grain weight was calculated from the weight of 200 grains and adjusted to 85% dry matter. Protein was calculated by determining the N content of finely ground samples, using the Near Infra Red GAC III Dicky John instrument, which was calibrated by reference to representative samples determined by the Dumas using a Leco nitrogen analyser (Model FP 228) method, and multiplying by a factor of 5.8 and 6.25 for wheat and barley, respectively.

Representative soil samples were taken from each plot, annually in September, and analysed at the Soil Laboratory, Johnstown Castle, using standard methods (Byrne, 1979), for soil pH, phosphorus (P), potassium (K), magnesium (mg), sodium (Na), calcium (Ca) and the trace elements manganese (Mn), copper (Cu) and zinc (Zn).

Production costs

Detailed costs, based on the actual input costs at three sample points (Carlow, Cork and Meath), of all material inputs were compiled for each year (Table 6). Machinery and other costs were based on Crop Costs and Returns compiled by J. O'Mahony, Teagasc.

The gross income for the winter cereal included the income from grain sales plus Area Aid. Grain prices were based on the actual prices obtained at the same three sample points. The income from malting barley was based on Minch Malt's price agreement with growers. Straw income was based on the actual price available ex Oak Park farm sales.

Table 6: Variable input costs for high and low inputs systems for the different cereals crops (1996-99)

Crop	High inputs					Low inputs				
	'96	'97	'98	'99	Mean	'96	'97	'98	'99	Mean
	Inputs costs (£/ha)**					Inputs costs (£/ha)**				
Winter wheat*	383	431	387	442	411	286	286	273	316	290
Winter barley*	344	342	334	354	344	242	228	228	235	233
Winter oats	351	330	324	325	333	257	229	198	222	227
Spring barley	221	224	186	242	218	161	157	141	175	158

* Mean of three treatments
** Cost of seeds, fertiliser and pesticides including interest

RESULTS

Soil fertility

There has been little change in soil pH over the five-year period (1994-99). Samples taken from each plot in September 1994 show that mean pH was slightly above 6.9 (Fig. 1). Mean pH values fell slightly in 1997 and 1998 to slightly below 6.9, but the mean pH value was restored to its original level (>6.9) in 1999 by the application of lime (10 t/ha) in autumn 1998 to a portion of the experimental area (half of block 4) where pH values were initially lower than the rest of the field.

Soil phosphorus (P) levels were generally very high (+18 mg/l) when the experiment commenced in 1994, but in September 1999 the soil P values had dropped considerably, even where P was applied annually. Despite the application of the calculated amount of P to the high inputs crops, residual P levels decreased from a mean value of 19.5 to 15 mg/l over the five-year period (Fig. 2). On the other hand, where no phosphorus was applied to the low inputs system the levels decreased from 18 to 10 mg/l, a reduction in mean P values of 8 mg/l over the five-year period (1996-99).

At the commencement of the experiment in 1994, potassium (K) levels in the soil were low to medium (80-90 mg/l). Consequently, the same amount of potassium was applied to both the high and low inputs systems and, as a result, there was little change in residual soil K levels over the five-year period.

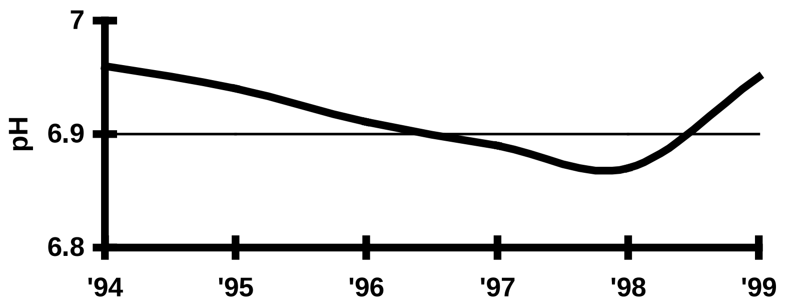

Fig. 1: Mean pH of the experimental site Knockbeg over the five-year period (1994-99)

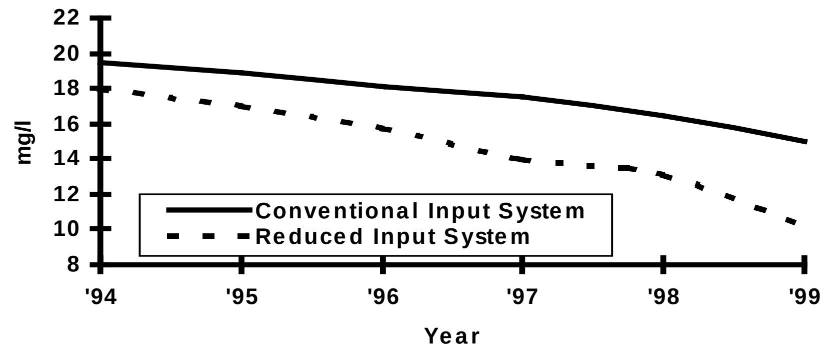

Fig. 2: Mean P levels of conventional and reduced inputs systems over the five-year period (1994-99)

Weed control*

The principal weeds present in the winter cereal crops, in order of density, were speedwell (*Veronica persica*), cleavers (*Galium aparine*), charlock (*Sinapis arvensis*), nipplewort (*Lapsana communis*), chickweed (*Stellaria media*), red deadnettle (*Lamium purpureum*), knotgrass (*Polygonum aviculare*), fathen (*Chenopodium album*), fumitory (*Fumiaria offininalis*) and groundsel (*Sececio vulgaris*). In spring barley the principal weeds present, in order of density, were knotgrass, nipplewort, and fathen. The weed flora remained unchanged, but there was a gradual increase in weed numbers between 1997 and 1999.

Herbicide application gave good weed control in the high inputs system throughout the period (1997-99), but the low herbicide applications gave reduced weed control in winter wheat and spring barley. Control of cleavers, in the high inputs system, was generally satisfactory in the initial years (1997 and 1998). However, in 1999, the low herbicide application (half rate diflufenican/IPU) gave reduced control of cleavers and groundsel, especially in the continuous winter wheat (Table 7).

Table 7: Effect of normal and half rate applications of difluferican/IPU (Cougar) on the control of annual weeds in winter wheat grown in different rotations (1997-99)

Inputs system	Rotations	Year 1997	1998	1999
High	Non cereal break-crop	**10	10	10
	Cereal break-crop	10	10	10
	Continuous	10	10	9
Low	Non cereal break-crop	10	10	10
	Cereal break-crop	10	10	9
	Continuous	9	9	5

** 10 = total weed control, 0 = no control

* Contributed by B. Mitchell

Field fauna*

Effect of inputs

In 1998 and 1999 the number of ground beetles, earthworms and slugs captured in high – and low – input wheat plots did not differ significantly (Tables 8–11). Low-input plots had fewer rove beetles than high-input plots. The reason for this is not clear, but the difference was significant in the cereal break-crop rotation in 1998 (Table 8).

Aphids were plentiful in 1999 and were significantly more numerous in the low-input plots than in the high-input plots of the cereal rotation. Previous work, however, had shown that aphid numbers were greater in wheat crops which had received high levels of N (Heinz and Daebeler, 1976; Schaefer *et al.,* 1979; *Gash et al.,* 1996).

Effect of rotation

The effect of crop rotation on numbers of the various faunal groups, captured in winter wheat, in 1998 and 1999 is shown in Table 12. Rotation had a major effect on slug numbers. The non-cereal break-crop rotation had significantly more slugs than the cereal break-crop rotation in each of the two seasons.

Rove beetle and money-spider numbers were greater in the cereal break-crop rotation than in the non-cereal break-crop rotation. The differences were significant for spiders in 1998 and for rove beetles in 1999. Rotation had no effect on the numbers of earthworms or aphids.

* Contributed by T. Kennedy

Table 8: The mean number of ground beetles, rove beetles and money-spiders per pitfall trap captured in winter wheat receiving high – and low-inputs, 1998

Fauna	Non cereal break-crop		Cereal break-crop		s.e.d.
	High	Low	High	Low	
Ground beetles	112.13	102.0	84.8	92.1	N.S.
Rove beetles	42.25	34.1	60.5	43.3	8.74
Money-spiders	94.6	98.3	122.5	120.3	4.96

Table 9: The mean number of ground beetles, rove beetles and money-spiders per pitfall trap captured in winter wheat receiving high – and low-inputs, 1999

Fauna	Non cereal break-crop		Cereal break-crop		
	High	Low	High	Low	s.e.d.
Ground beetles	118.8	80.6	110.8	115.8	N.S.
Rove beetles	42.0	33.3	65.1	49.0	10.81
Money-spiders	163.3	115.1	107.8	183.8	26.01

Table 10: Earthworm populations (no/m^2) and biomass (g/m^2) in winter wheat receiving high- and low-inputs (1998 and 1999)

Date of Sampling		Non cereal break crop		Cereal break-crop		
		High	Low	High	Low	s.e.d.
27/8/1998	Number	105.0	101.5	89.0	91.0	N.S.
	Biomass [a]	15.01	16.57	25.54	19.23	N.S.
18/8/1999	Number	128.0	117.5	91.5	126.0	N.S.
	Biomass [a]	30.13	26.62	17.47	31.16	N.S.

[a] Weighed on the day of sampling NS = not significant

Table 11: The mean number of slugs per pitfall trap captured in winter wheat receiving high- and low-inputs. Trapping for a three-week period in 1998 and 8 weeks in 1999

Date of sampling	Non cereal break crop		Cereal break-crop		
	High	Low	High	Low	s.e.d.
27/8/1998	97.6	87.4	63.5	63.9	9.94
18/8/1999	167.3	182.9	140.9	98.4	26.79

Table 12: The effect of crop rotation on the numbers of various field fauna collected in pitfall traps (1998 and 1999)

Fauna	Non cereal break-crop	Cereal break-crop
	1998	
Ground beetles	107.1*	88.4
Rove beetles	38.2	51.9
Money-spiders	96.5	121.4**
Slugs	92.5**	63.7
Earthworms [a]	103.3	90.0
Earthworms [b]	15.8	22.4
	1999	
Ground beetles	99.7	113.3
Rove beetles	37.6	57.1*
Money-spiders	139.2	145.7
Slugs	175.1**	119.6
Earthworms [a]	122.8	108.8
Earthworms [b]	28.4	24.3

* = Significant difference between rotations ($P<0.05$)
** = Significant difference between rotations ($P<0.01$)
a = number/m^2
b = g/m^2

Foliar Diseases*

The principal foliar disease of winter wheat in all four years (1996 – 99) was Septoria (*Mycosphaerella graminicola*). The amount of disease varied between seasons, with high levels in 1996, moderate levels in 1998 and low amounts in the other two seasons

Table 13: Effect of conventional and reduced rate fungicide programmes on the percentage necrosis due to Septoria on the second leaf of Winter Wheat (1996 – 1999)

Inputs system	Rotations	Year				
		1996	1997	1998	1999	Mean
		% Necrosis (2nd Leaf)				
High	Non cereal break-crop	19.8	3.8	27.2	4.9	13.9
	Cereal break-crop	43.4	4.2	15.2	2.3	16.3
	Continuous	33.4	2.2	9.1	2.2	11.7
Low	Non cereal break-crop	49.5	1.8	11.9	5.1	17.1
	Cereal break-crop	69.8	2.0	8.6	3.5	21.0
	Continuous	54.4	2.8	6.8	3.6	17.0
	s.e.d.	5.57	1.12	3.6	1.3	-

In 1996, when Brigadier was grown in both systems, the level of disease was greater in the low inputs system than the high inputs system. In the other three years the low inputs system had lower disease levels probably as a result of the greater resistance of the variety Ritmo.

The effect of rotation on disease necrosis varied from season to season (Table 13). In 1996 the highest disease levels occurred on the winter wheat grown in the cereal break-crop rotation but in 1998 the highest levels of Septoria occurred in the non cereal break-crop and there was no difference between rotations in the other two years.

* Contributed by B. Dunne

Rhynchosporium was the principal foliar disease of winter barley in 1996, 1998 and 1999 with powdery mildew dominant in 1997. There were traces of brown rust in 1998 and net blotch in 1999. The overall disease levels were low over the four years with the reduced input treatment having slightly higher disease levels than the conventional treatment (Table 14).

Table 14: Effect of conventional and reduced rate fungicide programmes on percentage necrosis on the second leaf (due to foliar disease) of winter barley (1996-1999)

Inputs system	Rotations	Year 1996	1997	1998	1999	Mean
		% Necrosis (2nd Leaf)				
High	Non cereal break-crop	4.9	0.3	8.5	4.3	4.5
	Cereal break-crop	5.8	0.2	4.6	8.0	4.7
	Continuous	3.0	0.7	4.5	8.7	4.2
Low	Non cereal break-crop	5.0	1.7	9.5	7.5	5.9
	Cereal break-crop	3.0	2.0	7.0	11.5	5.9
	Continuous	2.7	0.4	9.0	13.9	6.5
	s.e.d.	2.51	0.96	2.95	3.82	-

The amount of foliar disease on spring barley was low in all years except 1997 when levels were moderate. In 1999 the main disease present was Rhynchosporium while powdery mildew was the dominant disease in the other three years. There was no significant difference in the amount of leaf disease between the conventional and low input systems.

Disease levels in winter oats were low over the four years on both the conventional and reduced treatments

Grain yields

Winter wheat consistently gave the greatest yields over the four-year period (Tables 15, 16, 17). However, yields were low in 1998 as a result of severe lodging (Table 18). Mean grain yields of winter wheat over the 4-year period were greater than 10 tonne per hectare in all treatments. The low inputs system gave lower yields than the high inputs system in all four years but the differences were significant only in two years (1997 & 1999) (Table 15). The reduction was generally less than 5% (0.5 t/ha).

Table 15: Effect of high and low inputs systems on the grain yield of winter wheat grown in different rotations (1996-99)

Inputs system	Rotations	Year				Mean
		1996	1997	1998	1999	
		Grain yield (t/ha at 85% DM)				
High	Non cereal break-crop	9.49	12.95	8.91	10.39	10.48*
	Cereal break-crop	10.13	13.30	9.75	10.66	10.96
	Continuous	9.88	12.73	9.05	10.18	10.46
Low	Non cereal break-crop	9.05	12.21	9.20	9.79	10.06
	Cereal break-crop	9.56	12.43	9.11	9.91	10.25
	Continuous	9.90	12.16	8.53	9.56	10.04
	s.e.d.	0.368	0.130	0.393	0.215	0.156

*There was a significant difference between systems ($P<0.001$) and also between rotations ($P<0.001$). There were no significant interactions between years, systems and rotations.

Winter wheat, grown in the cereals rotation after winter oats, gave greater yields than the other two treatments (Table 15). The increased amount of lodging in the non cereal break-crop winter wheat may have reduced the grain yield in that treatment. However, in 1997 (Table 18) and 1999, when there was little or no lodging, the cereal break-crop rotation winter wheat (grown after winter oats) still gave the largest yields.

The high winter barley inputs system gave consistently greater yields than the low inputs system in all four years. Mean yield reduction was 12% (Table 16). While it is not possible to identify the factors responsible for this yield reduction it is unlikely that it was due to greater levels of disease (Table 21).

There was no significant difference in the mean yield of winter barley grown in the three different rotations over the four-year period. However, in 1997 and 1999, when there was no lodging, the winter barley grown in the non cereal break-crop rotation (after turnip rape) gave greater yields than the cereal rotation and continuous winter barley in both systems. Lodging (mainly brackling) reduced the grain yield of winter barley grown in the non-cereal break-crop rotation in 1998 (Tables 16 and 19).

Table 16: Effect of high and low inputs systems on the grain yield of winter barley grown in different rotations (1996-99)

Inputs System	Rotations	Year 1996	1997	1998	1999	Mean
		Grain yield (t/ha at 85% DM)				
High	Non cereal break-crop	8.78	9.32	8.30	9.98	-
	Cereal break-crop	9.07	9.09	9.08	9.45	-
	Continuous	8.75	9.15	9.26	9.26	-
Low	Non cereal break-crop	8.06	7.99	7.52	9.31	-
	Cereal break-crop	8.07	7.39	7.70	8.39	-
	Continuous	7.35	7.51	8.13	8.60	-
	s.e.d.	0.360	0.146	0.241	0.199	-

The grain yield of winter oats, especially under the high inputs system, were consistently high (9-10 t/ha), except in 1998 when severe lodging in early June reduced grain yield considerably (Table 20). The low inputs system gave a mean yield reduction of 9% (Table 17) and was significantly lower than the high inputs system in three years out of four.

Table 17: Effect of high and low inputs systems on the grain yield of winter oats and spring malting barley (1996-99)

Cereal	Inputs system	Year 1996	1997	1998	1999	Mean
		Grain yield (t/ha at 85% DM)				
Winter oats	High	9.35	10.31	5.47	9.61	8.69
	Low	8.54	9.28	5.49	8.44	7.94
	s.e.d.	0.204	0.442	0.296	0.258	0.155
Spring barley	High	7.17	7.39	5.61	7.62	6.95
	Low	6.10	6.86	4.70	6.68	6.08
	s.e.d.	0.225	0.122	0.317	0.068	0.111

Table 18: Effect of high and low inputs systems on the amount of lodging of winter wheat grown in different rotations (1996-99)

Inputs system	Rotations	Year			
		1996	1997	1998	1999
		Lodging index			
High	Non cereal break-crop	40	4	95	0
	Cereal break-crop	1	0	78	0
	Continuous	0	0	54	0
Low	Non cereal break-crop	63	17	62	0
	Cereal break-crop	0	3	0	0
	Continuous	0	2	0	0
	s.e.d.	17.3	-	8.0	-

Table 19: Effect of high and low input systems on the amount of lodging of winter barley grown in different rotations (1996-99)

Inputs system	Rotations	Year			
		1996	1997	1998	1999
		Lodging index			
High	Non cereal break-crop	81	8	62	0
	Cereal break-crop	59	0	0	0
	Continuous	65	0	0	0
Low	Non cereal break-crop	86	1	67	0
	Cereal break-crop	58	0	17	0
	Continuous	65	0	14	0
	s.e.d.	6.2	-	-	-

Table 20: Effect of high and low inputs systems on the amount of lodging in winter oats and spring barley (1996-99)

Cereal	Inputs system	Year			
		1996	1997	1998	1999
		Lodging index			
Winter oats	High	0	65	92	0
	Low	0	24	96	0
	s.e.d.	-	8.5	7.9	-
Spring barley	High	0	58	0	0
	Low	0	0	0	0
	s.e.d.	-	4.8	-	-

The spring malting barley (cv. Cooper), grown under the high inputs system, gave significantly greater yields than the low inputs system in all four years (Table 17). The low inputs system gave a mean yield reduction of 12.5%. In 1997, the crop failed to meet malting barley standards due to the severe sprouting which occurred as a result of the prolonged rainfall and high humidity over a four-day period (August 1-4). Yields were low in 1998 due to severe infection by the leaf spotting disorder (Burke, 1998) and possibly to leaching of nitrogen due to high rainfall in March.

Table 21: Percentage leaf necrosis due to disease on the top three leaves of winter barley in the low and high inputs systems (1996-99)

Year	High inputs			Low inputs		
	% Disease necrosis			% Disease necrosis		
	Leaf 1	Leaf 2	Leaf 3	Leaf 1	Leaf 2	Leaf 3
1996	0	4	55	0	4	67
1997	0	0	4	0	1	9
1998	0	3	5	4	9	8
1999	0	7	11	0	11	15
Mean	0	4	19	1	6	25

Grain quality

Reduced inputs had little effect on grain quality ex-farm. Seasonal differences in hectolitre weight (kg/hl) or screenings were greater than the differences between rotations or systems (Tables 22 to 27). The higher levels of screenings in the winter barley low inputs system may have been due to inadequate nitrogen, or due to slightly poorer control of leaf diseases (Table 21). The higher rate of N applied to the high inputs system gave higher protein levels in all cereal crops, including malting barley (Table 28).

Table 22: Effect of high and low inputs systems on the hectolitre weight on winter wheat grown in different rotations (1996-99)

Inputs system	Rotations	Year				
		1996	1997	1998	1999	Mean
		Hectolitre weight (kg/hl)				
High	Non cereal break-crop	72.3	74.8	71.5	76.1	73.7
	Cereal break-crop	75.1	75.3	72.8	76.1	74.8
	Continuous	74.8	75.4	72.9	75.6	74.9
Low	Non cereal break-crop	72.4	75.3	71.6	75.9	73.8
	Cereal break-crop	75.1	75.0	71.6	75.0	74.2
	Continuous	75.8	74.4	69.0	74.1	73.3
	s.e.d.	0.62	0.61	1.08	1.05	-

Table 23: Effect of high and low inputs systems on the hectolitre weight of winter barley grown in different rotations (1996-99)

Inputs system	Rotations	Year				
		1996	1997	1998	1999	Mean
		Hectolitre weight (kg/hl)				
High	Non cereal break-crop	66.0	64.6	63.2	66.5	65.1
	Cereal break-crop	66.5	64.3	65.8	66.0	65.7
	Continuous	65.9	64.6	64.3	66.9	65.4
	Non cereal break-crop	64.9	63.9	62.8	65.0	64.2
Low	Cereal break-crop	65.3	62.9	63.1	62.9	63.8
	Continuous	64.8	63.3	63.6	64.8	64.1
	s.e.d.	0.62	0.51	0.61	0.60	-

Table 24: Effect of high and low inputs systems on the hectolitre weight of winter oats and spring barley (1996-99)

Crop	Inputs system	Year				Mean
		1996	1997	1998	1999	
		Hectolitre weight (kg/hl)				
Winter oats	High	58.7	52.9	47.6	54.0	53.3
	Low	58.4	54.3	49.2	52.1	53.5
	s.e.d.	0.78	0.66	0.54	1.09	-
Spring barley	High	67.5	59.0	65.4	66.3	64.6
	Low	67.3	60.0	64.0	65.4	64.2
	s.e.d.	1.01	0.46	1.28	0.32	-

Table 25: Effect of high and low inputs systems on the amount of screenings in winter wheat grown in different rotations (1996-99)

Inputs system	Rotations	Year				Mean
		1996	1997	1998	1999	
		Screenings %				
High	Non cereal break-crop	2.8	0.9	1.8	2.4	2.0
	Cereal break-crop	2.3	0.8	2.0	2.3	1.9
	Continuous	2.0	0.7	1.9	2.7	1.8
Low	Non cereal break-crop	3.0	1.0	1.5	2.9	2.1
	Cereal break-crop	2.0	1.1	1.3	3.2	1.9
	Continuous	1.8	1.1	1.5	3.6	2.0
	s.e.d.	0.53	0.10	0.28	0.34	-

Table 26: Effect of high and low inputs systems on the amount of screenings in of winter barley grown in different rotations (1996-99)

Inputs system	Rotations	Year				
		1996	1997	1998	1999	Mean
		Screenings %				
High	Non cereal break-crop	2.7	4.4	5.5	1.9	3.6
	Cereal break-crop	2.4	2.3	4.4	3.1	3.0
	Continuous	2.7	2.2	3.1	2.4	2.6
Low	Non cereal break-crop	2.8	5.3	7.4	2.6	4.5
	Cereal break-crop	3.3	3.6	5.5	4.4	4.2
	Continuous	4.6	4.2	4.3	3.0	4.0
	s.e.d.	0.62	0.31	0.73	0.39	-

Table 27: Effect of high and low input systems on the amount of screenings in winter oats and spring barley (1996-99)

Crop	Inputs system	Year				
		1996	1997	1998	1999	Mean
		Screenings %				
Winter Oats	High	5.6	4.2	8.9	2.7	5.4
	Low	4.9	3.3	10.0	2.3	5.1
	s.e.d.	0.45	0.39	0.47	0.27	-
Spring Barley	High	2.3	10.1	7.5	4.3	6.1
	Low	2.2	7.7	5.8	4.8	5.1
	s.e.d.	0.35	2.15	1.66	0.52	-

Table 28: Effect of increased fertiliser N on the protein content of malting barley, cv. Cooper (1996-99)

Inputs system	Fertiliser N (kg/ha)	Year				
		1996	1997	1998	1999	Mean
		Protein %				
High	137.5	9.0	10.4	10.0	10.3	9.9
Low	105	8.6	9.6	8.9	9.3	9.1
	s.e.d.	0.21	0.37	0.16	0.39	0.15

Financial returns

Over the four years of the experiment the winter wheat gave the greatest financial returns, followed by spring malting barley (Table 29-31). Winter wheat grown in rotation after winter oats (cereal break-crop) gave better financial returns than the other two treatments (Table 29).

Table 29: Effect of high and low inputs systems on the gross margins of winter wheat grown in different rotations (1996-99)

Inputs system	Rotations	Year				
		1996	1997	1998	1999	Mean
		Gross margins (£/ha)*				
High	Non cereal break-crop	628	699	444	485	564
	Cereal break-crop	664	727	517	527	609
	Continuous	638	676	451	482	562
Low	Non cereal break-crop	694	794	594	547	657
	Cereal break crop	730	811	586	608	684
	Continuous	767	787	531	575	665
	s.e.d.	-	-	-	-	-

* Gross income of grain and straw (including area-aid)

Table 30: Effect of high and low inputs systems on the gross margins of winter barley grown in different rotations (1996-99)

Inputs system	Rotations	Year 1996	1997	1998	1999	Mean
		Gross margins (£/ha)*				
High	Non cereal break-crop	579	507	450	571	527
	Cereal break-crop	599	489	515	527	533
	Continuous	566	494	532	509	525
Low	Non cereal break-crop	616	524	502	644	571
	Cereal break-crop	619	476	517	567	545
	Continuous	546	486	556	586	544
	s.e.d.	-	-	-	-	-

* Gross income of grain and straw (including area-aid)

Table 31: Effect of conventional and reduced input systems on the gross margins of winter oats and spring barley (1996-99)

Cereal	Inputs system	Year 1996	1997	1998	1999	Mean
		Gross margins (£/ha)*				
Winter oats	High	578	577	195	557	477
	Low	609	608	343	564	531
	s.e.d.	-	-	-	-	-
	High	749	467**	470	618	576
	Low	684	505	456	616	565
	s.e.d	-	-	-	-	-

* Gross income of grain and straw (including area-aid)
** Did not meet malting barley standard

Although the high inputs system gave greater yields than the low inputs system, the financial returns were greater from the low inputs system. The financial returns from winter wheat in the low inputs system were greater in all three rotations and in all four years (Table 29). The low inputs system gave greater returns for winter oats in all four years (Table 31). In the case of winter barley, the low inputs system gave greater financial returns in three years out of four, with little difference between the two systems in 1997 (Table 30). However, for malting barley the high inputs system gave the best financial returns in two years out of four, with little difference between the two systems in 1999 (Table 30)

The effect of the two inputs systems on production costs (cost of producing a tonne of grain) are shown in (Table 32). The low inputs system reduced the cost of producing the winter cereals by approximately £10 per tonne on average over the four-year period. The reduction was much smaller in the case of spring malting barley. However, the data shows that unit production costs were very dependent on grain yield, which was largely controlled by seasonal factors. Thus, the very high yields of winter wheat in 1997 reduced unit costs dramatically, while the poor yields of winter oats and malting barley in 1998 increased unit costs considerably.

Table 32: Costs of producing a tonne of grain under the conventional and reduced inputs systems (1996-99)

Cereal	Inputs system	Cost/tonne of grain				
		1996	1997	1998	1999	Mean
Winter wheat	High	71	57	75	72	69
	Low	61	47	63	64	59
Winter barley	High	72	68	71	67	71
	Low	63	65	65	59	63
Winter oats	High	71	60	110	63	76
	Low	65	54	83	60	65
Spring barley (malting)	High	66	66*	77	65	69
	Low	67	59	81	63	68

* Did not meet malting barley standard

CONCLUSIONS

- Winter wheat gave the greatest yields, followed by winter oats and winter barley. The wheat grown in rotation after winter oats gave significantly higher yield than wheat grown continuously or after the non-cereal break-crop.

- The low inputs system gave lower yields for all crops in all four years. The difference in yield between the two systems, was relatively small on average over the four years (less than 5%) for winter wheat, but was much larger (9-12%) for winter barley and winter oats.

- Low crop inputs had little or no effect on grain quality ex-farm (hectolitre weight or screenings). The increased N applied in the high inputs system increased grain protein in all cereals, including malting barley.

- Slug numbers were significantly greater in the cereals (wheat and barley) grown after a non-cereal break-crop than in the other rotations but inputs system had little effect on numbers.

- Weed control was satisfactory in the high inputs system but the low-dose herbicide applications gave reduced weed control in spring barley in 1998 and in the continuous winter wheat in 1999.

- There was a gradual reduction in soil P levels over the five-year period (1994-99) but the rate of reduction was greater under the low inputs system, which received no P.

- The winter cereals grown under the low inputs system gave greater financial returns than the high system but spring malting barley gave the best returns in three years out of four when grown under the high inputs system.

- The costs of producing a tonne of grain were considerably lower under the low (decision-based) inputs system.

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