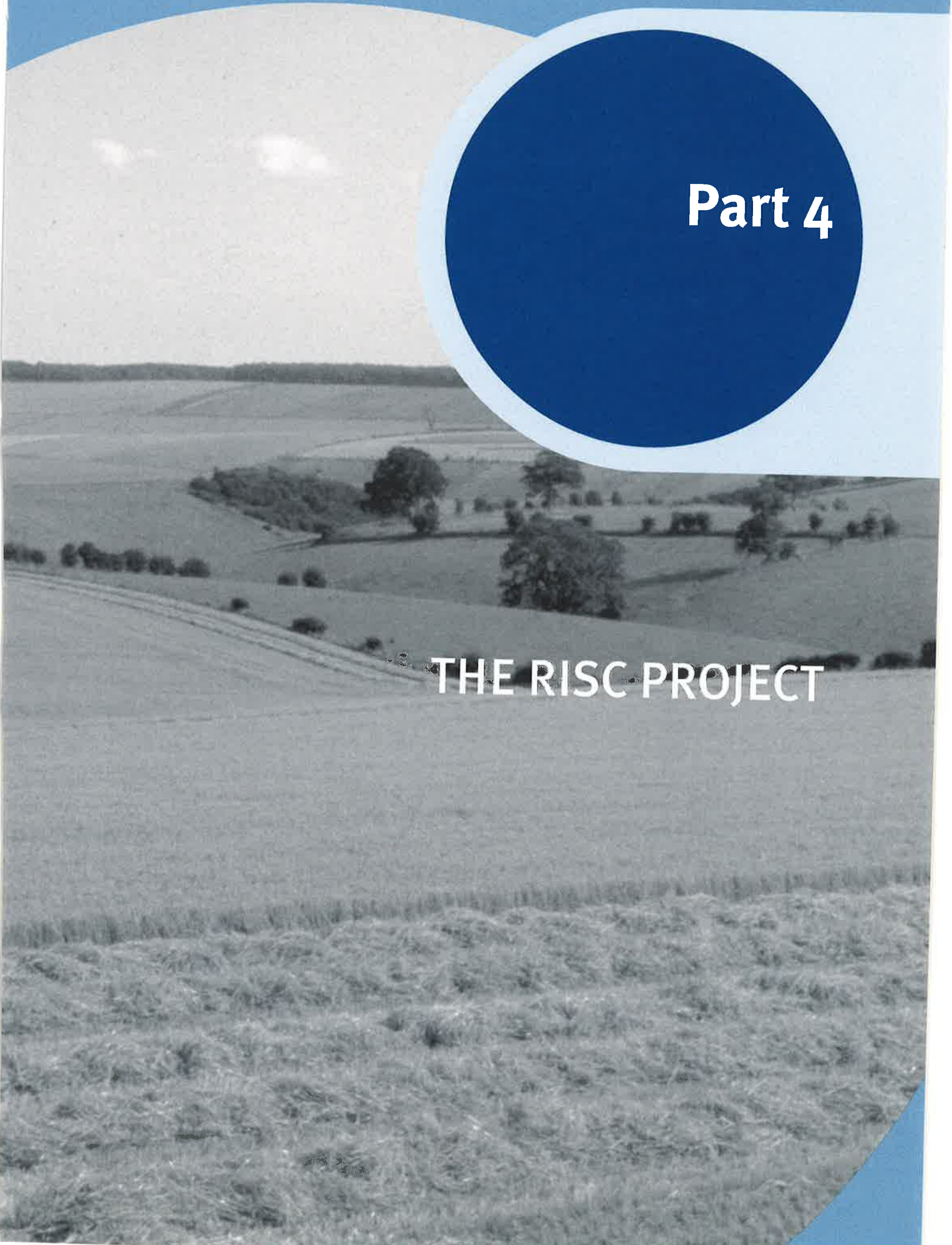
Part 4

THE RISC PROJECT



RISC: THE EFFECTS OF REDUCING INPUTS OF FERTILISER AND AGROCHEMICALS ON CROPS IN NORTHERN IRELAND

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Arable crops in Northern Ireland

Arable cropping in Northern Ireland occupies only about 6% of agricultural land and the principal crops grown are spring barley (29,000 ha) and potatoes (12,000 ha). Winter cereals, oilseed rape and other break crops are grown mainly on the more specialist arable farms in Co. Down, Co. Londonderry and North Antrim. Potatoes are grown for both seed and ware, although the seed industry has been in decline and ware producers are having to improve the quality of the crop to meet the demands of the major supermarket groups which have recently moved into Northern Ireland. Cereal growers benefit from the fact that Northern Ireland does not produce enough grain to meet the needs of its large livestock industry. Belfast grain prices were therefore based on the English price plus a £15/t shipping cost. Over the last five years, Northern Ireland crops have achieved yields that have usually been slightly below the average for the United Kingdom as a whole (**Table 4.1.1**). Although occasionally better yields are achieved than the United Kingdom average, in the difficult season of 1993 cereals in Northern Ireland yielded more than a tonne less than the United Kingdom average. Comparisons of variable costs between Northern Ireland and the east of England (Kirke, 1994; Murphy, 1995) show that total variable costs of cereal growing in Northern Ireland are similar to those in England, but the breakdown of costs is different in that less is spent by Northern Ireland cereal producers on pesticides but more on fertiliser. This latter effect is likely to be due to higher fertiliser prices rather than higher application rates.

RISC

The 'Reduced Input Systems of Cropping' (RISC) experiment was initiated in 1991 by the Department of Agriculture for Northern Ireland (DANI) with the aim of investigating the effects of adopting reduced input strategies for fertilisers and agrochemicals on the yield, profitability, sustainability and environmental impact of crops under Northern Ireland conditions. The RISC Project has followed closely the protocols of the TALISMAN study so that comparisons can be made across the United Kingdom (Bowerman, 1993). The RISC experiment was completed in 1999 and in this chapter the results of the first six years of the experiment, conducted at the Agricultural Research Institute of Northern Ireland, Hillsborough, are reviewed.

Reducing Agrochemical use on the Arable Farm: The TALISMAN and SCARAB Projects.

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Design of RISC

The rotations that are being compared are a six-course arable rotation and a four-course arable rotation with a two-year grass break (**Table 4.1.2**). In order to allow for seasonal differences, each rotation has been included twice, but starting at different points in the rotation (Year 1 and Year 4). Superimposed on the crops in each rotation are treatments with different combinations of fertiliser and pesticide inputs (**Table 4.1.3**). Fertiliser nitrogen (N), phosphate (P) and potash (K) were applied at either the rates recommended by DANI (Bailey, 1993) or at 50% of those rates. No fertiliser was applied to the minimum-input plots. Pesticides use was based on current farming practice as indicated by pesticide surveys in Northern Ireland (Jess *et al.*, 1993 & 1995) and advice from DANI staff. Rates recommended on the product label were used in the Current Farming Practice (CFP) treatment whereas 50% of the CFP rate, or less, was applied in the Low Input Approach (LIA) treatment. A rate lower than 50% could be selected when it was expected that the yield response to the agrochemical might be less than 10%. In the LIA treatment, all pesticides (herbicides, fungicides and insecticides) were applied at the reduced rate. Low-rate herbicide, fungicide and insecticide treatments were also included in sub-plots as separate treatments with other agrochemicals applied at full-rate.

In the Integrated Low Input Approach (ILIA) a more flexible approach was taken, choosing treatments which it was hoped would minimise the effects of the reduced rate of fertiliser and chemical use. In some cases, crop varieties were changed to ones with higher disease resistance and in others the herbicide or fungicide chosen was changed to one more likely to be effective at the lower rate. Two further treatments were included to provide ‘controls’: continuous spring barley (CSB) which received the full fertiliser rates together with CFP- or LIA-rate pesticides; and a minimum-input treatment (MIN) which received no fertiliser and only those pesticide treatments deemed necessary to prevent crop failure.

The experiment was laid out in main plots (10 m x 20 m) with three replicates. The fertiliser treatments were applied to the main plots which were subdivided into five plots (4 m x 10 m) to which the CFP, LIA, Low Herbicide, Low Fungicide and Low Insecticide treatments were applied. In a fourth replicate, larger plots (10 m x 40 m) were used which were not sub-divided. These plots have been monitored for invertebrate activity using pitfall traps that were emptied weekly from April to September. The crop varieties used were selected from current recommended lists. In the arable/grass rotation, it was assumed that cow slurry was available and therefore applications of slurry were made to the crops in this rotation as appropriate.

The site of the Hillsborough experiment was previously under intensively managed grass for about 15 years and the soil type is a sandy clay loam with a pH of about 6.2. Disease levels on the crops were regularly recorded and both weed numbers and biomass were recorded where appropriate. Yields and quality characteristics were determined on the harvested crops.

The calculation of gross margins was based on standard selling prices for grain, straw, potatoes and oilseed rape (**Table 4.1.4**). Where appropriate, arable aid payments have been added at the 1996 rate of £236.6/ha for cereals and £447.0/ha for oilseeds. No account has been taken of the set-aside requirement. Variable costs have been included for seed, fertilisers and agrochemicals based on actual invoiced prices. No contractors’ costs, drying or storage costs are included other than for harvesting and bagging potatoes.

Where the plots were sown with grass in the rotation, fertilisers were applied at full and half rates in the same way as for the arable crops. In the CFP and LIA plots, three silage cuts were taken while in the ILIA plots two cuts were taken followed by grazing with sheep. In the MIN plots, which were sown out with a higher proportion of clover in the sward, sheep were grazed throughout the year. Although grass yields were measured, they are not reported here.

Yields with full-rate inputs

In the first season, spring barley was sown in all the treatments except arable/grass Phase I and the high initial fertility of the ground was reflected in an average yield of 6.4 t/ha with a fertiliser N application of only 40 kg/ha (**Table 4.1.5**). In subsequent years, yields in the continuous spring barley plots remained relatively constant at between 5.1 and 5.4 t/ha although N applications were increased to 110 kg N/ha. Yields in the arable and arable/grass rotations were at or above Northern Ireland average figures in most cases, with potatoes yielding 39 to 40 t/ha of ware-sized tubers, winter barley yielding from 5.4 to 7.7 t/ha and oilseed rape 3.1 to 3.3 t/ha. The poor autumn weather conditions in 1992 led to delays in the harvesting of the potatoes and the following winter wheat could not be sown until January. This late-sown wheat performed very poorly, yielding below 4 t/ha. Wheat after oilseed rape in the same year performed better but still yielded only 6.5 t/ha. This was, however, substantially above the Northern Ireland average for 1995, which at 5.6 t/ha reflected a poor year for wheat. Wheat performed better in 1996 in the arable/grass rotation when it yielded over 8 t/ha, reflecting the continuing effect of the grass break. In the arable rotation, however, it yielded only 6.7 t/ha at the same fertiliser level, and overall wheat performed below the true potential of the crop. Spring barley in the arable and arable/grass rotations yielded better than when grown continuously, yielding 6.4 to 6.6 t/ha in 1994. Winter barley also yielded well with over 7 t/ha in 1992, 1994 and 1995.

Excluding the wheat after potatoes in 1993, gross margins ranged from £464 for the continuous spring barley in 1996 up to £1,193 for potatoes in the arable rotation in 1992. The relatively high yields of both spring and winter barley in the arable and arable/grass rotations resulted in gross margins for these crops similar to, or higher than, the better wheat crops.

Impact of reduced inputs

The average results for each of the crops are summarised using the means from all occasions on which the crop was grown, irrespective of which rotation it occurred in (**Tables 4.1.6 & 4.1.7**).

Cereals

With the cereals, LIA agrochemicals with full-rate nitrogen resulted in less than 5% reduction in yield and improved gross margins by £14, £34 and £35 per hectare per annum for spring barley, winter barley and winter wheat respectively. Where half-rate fertiliser was used, CFP yields were reduced by 15% to 23% (the greatest effects being with wheat) and gross margins were from £43 to £82 lower than with full-rate fertiliser. At this fertiliser level, there was little difference between full-rate and half-rate pesticides in yield and so the gross margins were higher with spring barley and winter wheat where half-rate pesticides were used. With all three cereals, the ILIA had slightly better yields than the LIA and with winter barley and winter wheat gave gross margins that were £36 and £25/ha respectively higher than the CFP. However, some caution must be used when considering the ILIA, as these treatments were present only in Phase II of the rotations and the results are the means of only one or two crops in each case, compared with four to six crops for the CFP and LIA.

The factors contributing to the improved performance of the treatments receiving reduced-rate pesticides can be seen in **Table 4.1.6** in the responses to herbicide, fungicide and insecticide. In spring barley, half-rate fungicide and insecticide gave positive responses whereas half-rate herbicide did not. However, insecticide was applied to only one of eight crops being averaged and fungicide to two, so these results should be treated with caution. With winter barley, all three pesticides had positive individual effects on yield and gross margin although the effect in the LIA, which received half rates of all three, was much less than a sum of the three. The greatest benefits appeared to be from half-rate herbicide and half-rate insecticide. With winter wheat, however, neither half-rate herbicide nor half-rate fungicide on their own resulted in improved yields or gross margins. It is not clear, therefore, what factors contributed to the improved gross margin where both were used at half rate. The use of half-rate fungicide in wheat was however more damaging to yield than low-rate herbicide, reducing yield by over 13% and gross margin by £42. This contrasts with the trend in both winter and spring barley in which half-rate fungicide did not have a damaging effect on yields.

Oilseed rape and potatoes

The effects of reduced inputs in oilseed rape and potatoes were different from those in cereals (**Table 4.1.7**). Half-rate pesticides, even with full-rate N, reduced yields by 17% and 12% respectively and also reduced gross margins by £33 and £126/ha. In oilseed rape, the response to inputs was much less in 1992 than in 1995 reflecting the higher fertility of the site in the early years of the experiment. In 1992, reducing the fertiliser input from 200 kg N/ha to 100 kg N/ha did not significantly reduce yields and reducing the rates of other inputs also had little effect on yield. However, in the means over the two crops of oilseed rape, the yield reductions with reduced inputs in 1995 outweighed the beneficial effects in 1992. With half-rate fertiliser in 1995, yields were reduced by over 30%. Weed competition was particularly strong in all the reduced herbicide treatments as the decision had been taken not to apply herbicide rather than to apply the half rate. This decision, taken in the light of the insignificant effects of weeds in 1992, was misjudged and both grass and broad-leaved weeds competed strongly with the crop at the critical stage of growth, severely retarding its development.

With potatoes, both yields and gross margins were reduced where either half-rate fertiliser, half-rate pesticides or a combination of both were used. The effect of half-rate pesticides can mainly be attributed to poor weed control (**Table 4.1.8**) as the effect of applying half-rate fungicide alone was small and insecticides were not used on the crop. Half-rate fertiliser on its own also reduced yield and where half rates of both fertiliser and herbicide were used the effect was additive, yield reduction increasing from 13% with half-rate pesticides alone to 30% in combination with half-rate fertiliser, with corresponding gross margin reductions of £126 and £340.

Weed problems in the potatoes were particularly evident in the dry 1995 season when the soil-acting residual herbicide provided poor weed control. Where the potatoes were in the arable rotation, there appeared to be higher weed numbers than in 1992. Where potatoes followed grass in the grass/arable rotation, weed numbers were lower and competition effects were less marked.

Reduced-rate herbicide

When looked at over the whole experiment, weed biomass at harvest was consistently higher where half-rate herbicide was used (**Table 4.1.8**). While these differences were relatively small and insignificant in terms of crop competition such that the use of the reduced rate was more profitable in some cases, there is evidence that a build up of weed seeds has been taking place. The weed seed bank data show that although broad-leaved weed seed numbers increased from about 2,000/m^2 to 5,000/m^2 over the six seasons even with full-rate herbicide, the increase with half-rate herbicide was about three times greater, while with no herbicide seed numbers increased to nearly 30,000/m^2 (**Fig. 4.1.1**). With grass weeds, the competition from broad-leaved weeds where no herbicide was used probably prevented grass weeds from increasing while with half-rate herbicide, broad-leaved weeds were suppressed and grass weed seed numbers increased.

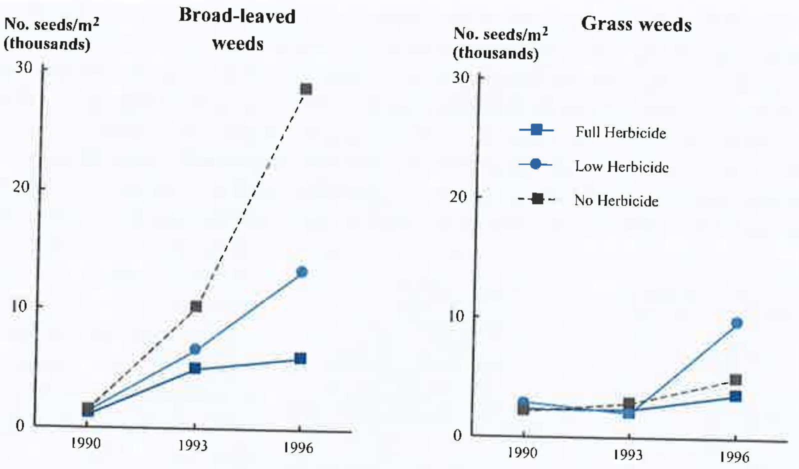

Figure 4.1.1. Numbers of weed seeds present in 1990, 1993 and 1996 in the soil of plots receiving full-rate, half-rate or no herbicide in the RISC Project.

The increased weed seed numbers could explain the severity of the weed problem in both the potato crop, where the conditions were poor for effective herbicide activity, and the oilseed rape in 1995, where herbicide was not applied. The weed problem with half-rate herbicide was also more severe where crop growth was poor as in the case of the winter wheat in 1993, sown in January after the late potato harvest (**Table 4.1.8**). The introduction of the grass break in the arable/grass rotation appeared to reduce the weed competition in the succeeding potato crop when compared with the potatoes following spring barley in the arable rotation.

Reduced-rate fungicide

The effects of reduced-rate fungicide treatments were much more closely related to the individual season and the type of crop rather than to the previous history of the ground. The greatest increases in disease levels with half-rate fungicide were found with the winter wheat at full-rate fertiliser, although marginal increases were found in some spring and winter barley crops (**Table 4.1.9**). These results are in agreement with the yield data which indicated significant yield reductions with the use of half-rate fungicide only in the wheat.

In neither season in which potatoes were grown was potato blight (*Phytophthora infestans*) a serious problem. Although blight periods did occur each year, the weather pattern did not continue to favour spread of the disease and this together with the relative isolation of the crops resulted in no recordings of blight even on the plots receiving reduced rates of fungicide. However, in view of the possible devastating effects of serious blight attacks, it would be unwise to conclude that a reduced-rate approach to blight fungicides could be recommended.

In the 1992 potato crop, the seed potatoes used in the CFP plots received metribuzin fungicide (Monceren) whereas the seed potatoes for the LIA plots did not. The resulting tubers from the LIA plots had significantly higher levels of several skin infections such as silver scurf (*Helminthosporium solani*), black scurf (*Thanetophorus cucumeris*) and skin spot (*Polyscytalum pustulans*), which would have seriously affected the marketability of the crop (**Table 4.1.10**).

Effect of site and rotation

The site of the RISC Project, which had been under intensively managed grass ley for about 20 years, had a high initial level of fertility which declined over the six years of this study. This decline can be seen when the difference in yield between the plots receiving full-rate N, half-rate N and no N are compared (**Fig. 4.1.2**). While it should be borne in mind that the half-rate and no fertiliser treatments included P and K as well as N, and that the no fertiliser treatments also received no agrochemicals, it is most likely that the major effects are related to the decline in mineralisation of N. In the first year, neither the half-rate nor the no fertiliser treatments reduced yields. With half-rate N, the yield differences in the arable rotation then progressively increased to reach a maximum of -30% in 1995, while in the arable/grass rotation the yield differences were less, reaching -26% in 1996. With no fertiliser inputs, yields in the arable rotation were nearly 67% lower by 1995, while in the arable/grass rotation the yield difference did not exceed 37%. In the arable/grass rotation, both the contribution of the grass ley and the cow slurry applications would have contributed to the lower yield differences.

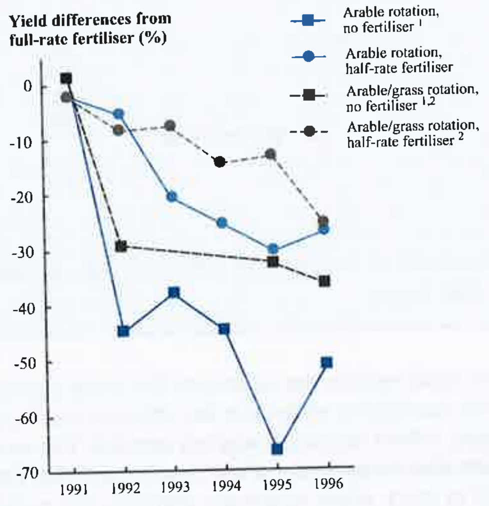

Figure 4.1.2. The effect of rotation and fertiliser treatment on RISC crop yields, meaned across rotation phases.

[1] No agrochemicals applied. [2] Cow slurry applied.

The effect of rotation can be seen most clearly after the two years of grass (1993 & 1994) in Phase II of the arable/grass rotation. In the following two seasons, both the arable/grass and the arable rotations had the same crops of ware potatoes and winter wheat. The management of the potatoes in the two rotations in 1995 was identical in terms of cultivations, planting, seed rate, herbicide, fungicide treatments and harvesting. The only difference was in the fertiliser N applications of 120 kg N/ha in the arable/grass rotation and 150 kg N/ha in the arable rotations which were set according to DANI recommendations (Bailey, 1993). The wheat grown in 1995/96 was managed identically in both rotations and the same level of fertiliser N was applied to both crops as this was the recommendation by DANI for crops more than one year after a ley.

With full rates of both fertiliser and pesticide treatments, there was very little difference in potato yield between the two rotations (**Table 4.1.11**). However, with reduced inputs of either fertiliser or pesticides, the yield of potatoes was reduced to a greater extent in the arable rotation than in the arable/grass rotation. The greatest difference between the two rotations was with minimum inputs which yielded only 13.3 t/ha in the arable rotation but 26.1 t/ha after the grass break. It should be borne in mind that the minimum input treatment received no fertiliser during the grass break. There was, however, a high clover content in the sward which was grazed with sheep throughout the two seasons and was not cut for silage or hay.

The poor yields with reduced-rate pesticides in the arable rotation, even with full-rate fertiliser, can be attributed almost entirely to increased weed competition which has already been discussed. The two-year grass break appeared to reduce the weed pressure in the following potato crop compared with two years of cereals

(**Table 4.1.8**) and may also have had a further carry-over effect in the winter wheat in 1996, in which there continued to be a lower weed biomass in the arable/grass rotation compared with the arable rotation.

The yields of wheat in the arable rotation in 1996 were poor, achieving only 6.7 t/ha even with full inputs (**Table 4.1.11**). It is likely that the recommended fertiliser application of 130 kg N/ha for wheat following potatoes (Bailey, 1993) was below the optimum. However, in the arable/grass rotation, yields up to 2 t/ha higher were achieved across all treatment levels at the same fertiliser N level. This would suggest that the grass break ploughed up in 1994 was continuing to have an effect in the second season. In detailed nitrogen mineralisation studies which were carried out on these plots (Allen *et al.*, 1998), it was found that following ploughing in March 1995, an additional 25, 41 and 90 kg N/ha had been mineralised in the arable/grass rotation with full-rate, half-rate and no fertiliser respectively by September 1995, and a further 85, 84 and 74 kg N/ha by September 1996.

The gross margins in the arable/grass rotation with reduced inputs of fertiliser or pesticide were substantially higher than in the arable rotation. With half-rate fertiliser and full-rate or integrated inputs of agrochemicals, gross margins were similar to those with full inputs of both, reflecting the small yield difference where half-rate fertiliser treatments were applied in the first year after grass.

Arthropod monitoring

The activity of carabid (ground) beetles and other invertebrates has been monitored by means of pitfall traps which were sampled weekly from April to September each year. Three traps were situated in each of the large 10 m x 40 m plots of block one and ten traps located in undisturbed margins of the field.

Particular interest has been taken in the carabid beetle species which are generally beneficial predatory species and can be used as an indicator of the effects of treatments on non-target invertebrates. The numbers of insects which are caught cannot, however, be taken as a reflection of their population size, but will reflect their activity and pattern of movement (Burn, 1992).

From 1991 to 1996, 43 species of carabid beetle were recorded. A summary of the numbers of species recorded in each treatment from May to August is given in **Table 4.1.12**, the average carabid numbers in **Table 4.1.13** and the 24 most common species are listed and described in **Table 4.1.14**. A number of these species such as *Pterostichus melanarius, Agonum dorsale* and *Nebria brevicollis* were also among the principal species recorded at the three sites of the TALISMAN Project on ADAS farms in England (Chapter 2.7) and would appear to be typical of arable crop habitats. The species recorded include those preferring both wet and dry habitats, thin or lush crops and arable and grass crops.

In the field margins, 27 species were recorded in 1992 and this fell to only 13 by 1996. However, in the plots, there was no evidence of a decline in species richness with similar numbers being recorded in 1992 and 1996. More than ten species were recorded in most plots each year, irrespective of which crop was being grown, and there was no evidence that species richness was increased in the LIA, ILIA or MIN treatments, which received lower levels of agrochemicals and fertilisers, compared with the CFP.

Low numbers of carabids were generally found in spring barley and potatoes, and the lowest numbers were in potatoes in 1995 which followed spring barley. Numbers also appeared to decline with successive years in grass, also in the field margin from 1992 to 1996 and in the arable/grass rotation (Phase II) from 1993 to 1994. Winter crops of wheat, barley and oilseed rape generally had higher carabid numbers, although this was not consistently the case. In the oilseed rape, various *Amara* spp. were found in high numbers on the MIN treatment in 1992 and the CFP and LIA in 1995. Carabid numbers remained low in the wheat which was sown late in 1993 and numbers failed to increase in the wheat following potatoes in the arable rotation in 1996. As with species richness, carabid numbers were not generally higher where agrochemical and fertiliser use was restricted. However, *Amara plebeja*, which is described as preferring low N situations (Anderson, 1997) was found in higher numbers on the LIA and MIN treatments. The lack of response to agrochemicals is not unexpected as insecticides and molluscicides were applied only in the autumn and any carry-over effect to the following year would be minimal.

Soil nutrient status

Each autumn, soil samples have been taken for the determination of soil pH, available phosphorus (P) and available potassium (K) in the top 15 cm, and mineral nitrogen (N) to a depth of 90 cm. Further data on the mineral N flux in the soil and nitrogen and carbon mineralisation in the soils of selected treatments in RISC have been gathered from the site from the start of the 1994/95 season and reported by Semple *et al.* (1997) and Watson *et al.* (1997).

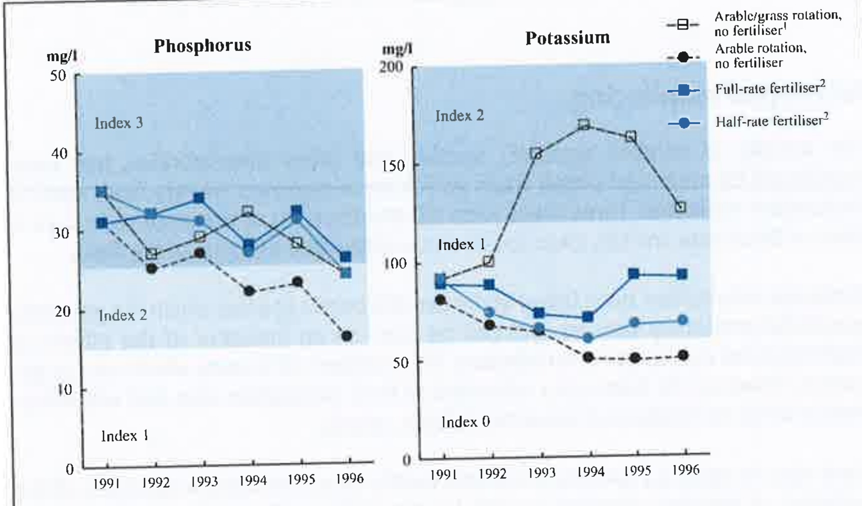

Figure 4.1.3. Changes in available soil phosphorus and potassium levels associated with RISC rotations and fertiliser treatments. ¹Cow slurry applied. ²Mean of both rotations.

Soil pH has remained at or close to the initial value of pH 6.2 in all treatments and has shown no consistent downward trend even though no lime applications have been made. Available P and K levels in the soil have, however, been influenced by the treatments and the mean results of the soil analyses are presented (**Fig. 4.1.3**). The initial phosphorus status was moderately high at Index 3 (30 to 35 mg/litre) and with the use of full recommended rates remained in the range 30 to 35 mg/litre until 1996 when it dropped to 26 mg/litre. The treatments receiving half-rate fertiliser showed a slight decline in available phosphorus up to 1995, maintaining values just above 30 mg/litre until 1996 when the value dropped to 24 mg/litre. Where no fertiliser or slurry was applied, the P content declined from 30 in 1991 to just above 15 mg/litre in 1996 but with the application of slurry, P levels closer to those of the half-rate fertiliser treatment were maintained.

Potassium levels in the soil were initially at Index 1, 80 to 100 mg/litre. With full recommended-rate fertiliser treatments, this showed little change between 1991 and 1996. The half-rate treatment maintained levels about 20 mg/litre below those with full-rate fertiliser but only with no fertiliser or animal manure did the status drop into the Index 0 band (**Fig. 4.1.3**). However, the application of heavy animal manure dressings to the minimum input plots in the grass rotation resulted in large increases in available K, particularly over the first three years of the project. It is not clear why all the treatments showed a decline in P status between 1995 and 1996 but it is possible that environmental factors such as low winter rainfall may have affected the results.

Mineral N present in the top 30 cm of soil in the autumn sampling from 1991 to 1995 was in the range 40 to 80 kg N/ha (**Fig. 4.1.4**) (Semple *et al.*, 1996). Ammonium-N generally formed a higher proportion than nitrate-N, particularly in 1995 when nitrate-N levels were below 10 kg N/ha. In 1994 and 1995, ammonium-N and total mineral N levels in the arable/grass rotation were significantly higher than in the arable rotation or continuous spring barley, this trend being evident in the plots receiving full-rate, half-rate and no fertiliser. It is likely that the contribution of the grass ley (1993 and 1994) and the application of animal manure contributed to the elevated ammonium-N levels.

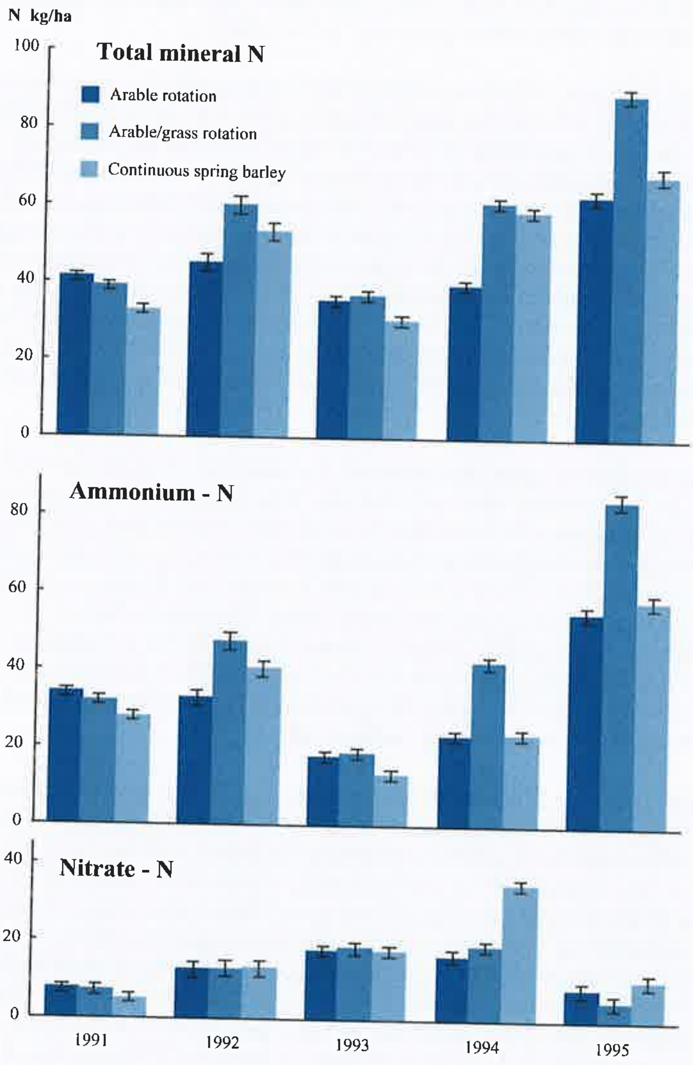

Figure 4.1.4. The effect of RISC crop rotations on total mineral N, nitrate-N, and ammonium-N present to a soil depth of 30 cm in autumn. Error bars show SEDs.

Overwinter mineral N losses, which were monitored in 1994/95 and 1995/96, ranged from zero to 150 kg N/ha, with wider fluctuations occurring in the ammonium-N content rather than nitrate-N (Semple *et al.*, 1997). In spite of having received no fertiliser or manure treatments since 1991, the arable rotation minimum input treatment still appeared to be losing more that 100 kg N/ha overwinter in 1995/96. More than 50% of the mineral N tended to be in the form of ammonium-N. As would be expected, greater mineralisation of N occurred in ground following the ploughing-up of grass as has already been discussed.

Discussion

Although a number of studies are taking place in the United Kingdom into the sustainability of reduced-input and integrated cropping systems (Webster, 1995), the RISC Project is the only one which includes a comparison of arable cropping with a mixed farming system including arable crops and grass. While such a comparison presents inherent difficulties when interpreting the economics of the whole farm system, it remains important to evaluate the potential contribution of grass leys to reduce the overall need for agrochemical use. In Northern Ireland, where grassland farming plays a predominant role, there is considerable scope for arable farmers to produce high quality crops which have required few applications of pesticides by making use of grass leys in the rotation.

In the first few years of the experiment at Hillsborough, the crop responses to inputs were dominated by the residual effect of the high fertility left by the grass ley which had been ploughed up when the experiment started (**Fig. 4.1.2**). In 1991, high spring barley yields of over 6 t/ha were achieved even where no fertiliser was applied, and weed numbers were low. In the second year, there was little difference in potato yield between the crop planted in the first year after grass (arable/grass rotation) or in the second year after grass (arable rotation). The oilseed rape with minimum inputs was more profitable than that with full inputs, owing to the relatively small response to fertiliser N. Over this period, the lower-input treatments tended to be more profitable than the full inputs for all the crops other than potatoes, in which even small reductions in yield had a large negative effect on gross margin.

As the experiment progressed, however, the nitrogen contribution from the soil declined and treatments receiving half-rate N or less became increasingly lower yielding. This can be seen most clearly in the half-rate fertiliser treatments of the arable rotation receiving full-rate pesticides which in 1991, 1992 and 1993 yielded 2.1, 6.3 and 6.5% less than with full-rate fertiliser but in 1994, 1995 and 1996 yielded 22.9, 26.3 and 41.4% less respectively. The introduction of the two-year grass break into the rotation clearly restored fertility to the soil (**Table 4.1.11**) and significantly improved the performance in at least the following two seasons. However, the benefits of the grass were not only in terms of fertility, but also helped to maintain a lower weed burden (**Table 4.1.8**).

The negative effects of reduced rate fertiliser N on yields and gross margins are similar to those from the associated TALISMAN Project (Bowerman *et al.*, 1995). There is little incentive, therefore, for farmers to reduce fertiliser N inputs to arable crops on the basis of crop management alone. Even when environmental considerations are taken into account (e.g. overwinter leaching of mineral N), the results available so far do not indicate that reducing the fertiliser N to half the recommended rate, or even zero, will necessarily reduce leaching as high leaching figures were being indicated from the minimum input plots under both rotations, particularly over the 1995/96 winter, the sixth year of the experiment. In common with other recent studies (Easson, 1995a), ammonium-N has remained at higher levels than nitrate-N in the soil even where arable cropping has been maintained for several seasons and no animal manures have been applied. These results contrast with those from arable soils in Eastern England where ammonium-N only forms a small proportion of total mineral N (Widdowson *et al.*, 1987).

The effects of reduced N, P and K in this project are, unfortunately, confounded as all fertiliser treatments were reduced proportionately. It is unlikely, however, that the reduced P and K applications had any direct effect on yields of cereals which are relatively tolerant of marginal levels of these nutrients. Some K deficiency symptoms were, however, noted on the foliage of potatoes receiving minimum inputs in the arable rotation. The fall in K Index of this treatment to 0 from 1994 onwards is not unexpected as the Silurian soil at Hillsborough is subject to K deficiency where inputs are not maintained. The soil indices for all the other treatments remained above Index 0 for K and all treatments remained above Index 1 for P. The application of heavy cow slurry dressings to the plots receiving no fertiliser maintained P at a level similar to half-rate fertiliser, but provided excess K which raised the soil status. The decline in the P status, where no fertiliser or slurry was applied, from Index 3 in 1991 to almost Index 1 in year 6 is of particular interest in the light of the current concern over the leaching of P from high index soils in Northern Ireland and in many European countries causing significant pollution to water bodies (Foy & Withers, 1995).

With both winter and spring barley, the use of reduced-rate fungicide applications generally provided adequate disease control and improved gross margins. However, in previous work, it has been found that significant yield reductions occurred in winter barley when fungicides for the control of rhynchosporium (*Rhynchosporium secalis*) were omitted (Easson, 1983). Yield benefits have also occurred when moderate to severe mildew attacks in spring barley have been controlled (Easson, 1986). Good disease control must therefore remain a priority in both winter and spring barley, but it appears to be generally the case that reduced-rate applications will be sufficient to control those infections which do occur. With winter wheat, however, yield losses occurred where reduced-rate fungicide was applied. Where wet weather conditions favour Septoria (*Septoria nodorum* and *Septoria tritici*), it is likely that reduced-rate fungicide treatments may provide inadequate disease control. Easson (1995b) reported a very high incidence of Septoria where fungicides were omitted from winter wheat in Northern Ireland.

The improved performance of the ILIA treatments in the cereal crops can be partly attributed to the choice of varieties with higher resistance ratings for the key diseases and partly to the use of more carefully selected fungicides. In the CFP and LIA treatments, the choice of pesticide was restricted to those more widely used, whereas in the ILIA treatment newer or less widely used fungicides could be chosen which it was believed would give a better result. The combination of these two factors contributed an improvement in gross margin of £40 to £60/ha compared with the LIA treatment in each of the cereals (**Table 4.1.6**).

The consistently higher weed biomass found following the use of half-rate herbicides (**Table 4.1.8**) is an indicator that weed problems may build up where reduced rates are used over an extended period. The increase in weed seed numbers in the soil (**Fig. 4.1.1**) are similar to those found in two of the sites of the TALISMAN Project in which the weed seedbank increased over the six-year rotation where reduced-rate herbicide applications were used (Chapter 2.3). The reduced weed burden in the crops of the arable/grass rotation following the ley, compared with those in the arable rotation, is important when considering the potential benefits of introducing a grass break into an arable rotation. If the aim is to reduce the use of agrochemicals and fertilisers while maintaining yields, then the grass break may contribute to both of these. However, the use of fertiliser on the grass itself must also be taken into account, which will be relatively high on intensive leys cut for silage.

A number of weed problems have occurred in the course of the experiment. Initially, following the ley, docks (*Rumex* spp.) were a problem in the LIA plots where a pre-ploughing glyphosate treatment was omitted. Couch grass (*Elytrigia repens*) populations also increased more rapidly in these plots although this was effectively controlled by half-rate pre-harvest glyphosate applications. These problems, together with those arising from the omission of herbicide from oilseed rape in 1995 and the poor performance of the soil-acting residual herbicide in potatoes in the same year, show that, as with fungicides, the total omission of herbicides can rarely be justified. While the careful use of reduced rates may often be cost-effective, there will always be situations in which full-rate treatments are necessary because a particularly difficult weed control situation has arisen or the risks associated with failing to give effective disease or weed control are too great. An example of this is with the blight sprays in potatoes where reduced rate applications pose too great a risk of total crop failure. However, it is recognised that in dry seasons, unnecessary applications of blight sprays may be being made. If improved prediction models could be developed, it may be possible to reduce blight sprays without endangering the crop (Cooke & Little, 1998).

The greatest cost benefits from the use of reduced rates in the RISC experiment appear to have been with reduced-rate insecticide, but because of the limited number of occasions on which they were used, mainly for BYDV protection of winter barley, care should be taken in interpreting the results. However, in the TALISMAN Project in which insecticides were more frequently used on a wider range of crops, no yield losses were recorded from using reduced rate insecticides and small but consistent savings were achieved (Chapter 2.6). While farmers have already widely adopted a reduced-rate strategy for herbicides and fungicides, little attention has been paid to reduced insecticide rates. This may be due to their relatively low cost and only intermittent use. Nevertheless, insecticides are the pesticides most likely to give rise to damaging environmental effects and closer attention should now be paid to reducing their application rates to the minimum necessary.

The environmental benefits of reducing agrochemical and fertiliser inputs are more difficult to quantify than changes in yield and gross margin. Any overall reduction in the amounts of these inputs introduced into cropping systems may be seen as beneficial and in this project the number of pesticide 'Units' applied, where one unit is taken to be the application of one product applied at the label recommended rate, has been reduced from 96 units with CFP to 43.5 with LIA or ILIA inputs over the first six years (**Tables 4.1.6 & 4.1.7**). From the limited invertebrate data which have been studied so far, the crop type and habitat have had a greater effect on carabids than level of pesticide input, an observation also reflected in the TALISMAN results. Other workers have highlighted the important effects of duration of crop cover, vegetation density and silage cutting on arthropod populations (Curry & Tuohy, 1978; Booij & Noorlander, 1992).

Overwinter losses of nitrate and phosphate into groundwater are also of environmental importance. However, the data obtained so far would indicate that N losses may be as high from the soils which have received no fertiliser N or slurry over the six years as from those receiving full treatments. Of greater long term importance may be the beneficial effect of lowering the soil P status in the minimum input treatments, and the indication this gives of how quickly soil P levels could be reduced in agricultural soils across the country.

Conclusions

While this study has shown that, particularly with cereals, reduced-rate applications of pesticides may only reduce yields slightly and improve profitability, it has also highlighted the need to consider rotation and longer term effects if reduced rates are to be maintained within a sustainable system. For example, the build up of the weed seedbank with repeated use of reduced-rate herbicide has been shown to create problems for crops such as potatoes or oilseed rape in seasons when weed control is difficult. The improved financial performance of the integrated low-input treatment (ILIA) compared with the low input (LIA), and the improved profitability of the crops following the two-year grass ley, both indicate that a reduced-rate approach to the use of agrochemicals is most likely to remain viable within a broad integrated approach to the whole farming system.

The use of reduced-rate fungicide treatments must be responsive to both the disease pressure occurring in each crop and the risk of financial loss, as the problems with Septoria control in wheat and late blight control in potatoes have shown. It is likely that the only reliable approach to reduced pesticide use in such situations will be through the use of forecasting and modelling built into computer-based decision support systems, rather than a prescriptive cutting of application rates.

The identification of environmental benefits from the adoption of reduced inputs of fertilisers and pesticides in this study has remained elusive. The mineral N studies of mineralisation and leaching have not indicated any less leaching from plots receiving reduced fertiliser N, and ploughing up of the two-year ley, while improving the profitability of subsequent crops with lower input levels, also creates a greater risk of leaching if ploughed in the autumn. The information gained on the rate of reduction of soil P is, however, of particular interest in the light of current concern about high phosphate levels in water bodies, which has been identified as coming from agricultural soils.

The limited information available from the pitfall studies has not indicated any consistent differences in carabid numbers between full-rate and half-rate pesticides, or even no pesticides. Over the six-year period of the RISC study, the diversity of carabid (ground beetle) species did not decline in the plots. It is clear, however, that crop type and season have large effects on carabid numbers, reflecting the findings of TALISMAN (Chapter 2.7).

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Table 4.1.1. Cereal yields in United Kingdom (UK) and Northern Ireland (NI) from 1991 (t/ha)*.

Cereal	Location	1991	1992	1993	1994	1995	1996
Winter wheat	U.K.	7.25	6.62	7.33	7.35	7.70	8.12
Winter wheat	N.I.	6.87	7.06	5.57	7.05	7.78	7.70
Winter barley	U.K.	5.91	6.16	5.73	5.83	6.20	6.61
Winter barley	N.I.	5.74	5.88	4.70	6.18	6.41	6.64
Spring barley	U.K.	4.80	4.93	4.50	4.78	5.10	5.43
Spring barley	N.I.	4.38	4.32	3.37	4.39	4.84	5.03

*Sources: Statistical Reviews of Northern Ireland Agriculture 1995 & 1996, Department of Agriculture for Northern Ireland, Belfast; Agriculture in the United Kingdom 1995, 1997, HMSO, London.

Table 4.1.2. Crop rotations used in the RISC experiment.

Rotation	1991	1992	1993	1994	1995	1996	1997
Arable							
Phase I	S. barley	Potatoes	W. wheat	W. barley	W. OSR	W. barley	S. barley
Phase II	S. barley	W. OSR	W. wheat	S. barley	Potatoes	W. wheat	W. barley
Arable/grass							
Phase I	Grass	Potatoes	W. wheat	S. barley	W. barley	Grass	Grass
Phase II	S. barley	W. barley	Grass	Grass	Potatoes	W. wheat	S. barley
Continuous s. barley	S. barley	S. barley	S. barley	S. barley	S. barley	S. barley	S. barley

W, Winter; S, Spring; OSR, Oilseed rape.

Table 4.1.3. Fertiliser and pesticide treatments used in RISC.

Pesticides	Full-rate fertilisers	Half-rate fertilisers	No fertilisers
All at recommended rates (CFP)	S, C	S, I	o
All at half of CFP rate (LIA)	S, C	S, I	o
Fungicide at half rate	S, C	S, I	o
Herbicide at half rate	S, C	S, I	o
Insecticide at half rate	S, C	S, I	o
Minimum pesticides	o	o	M

S = Standard treatments, arable and arable/grass rotations, Phases I and II.
I = Integrated treatments, arable and arable/grass rotations, Phase II only.
C = Standard treatments, continuous spring barley.
M = Minimum use of pesticides (arable and arable/grass rotations, Phase II only).
o = Not included.

Table 4.1.4. Standard prices and area payments applied in RISC.

Crop/Activities	Grain price	Straw price	Area payments
All cereal crops	£85 /t	£30 /t	£236.6/ ha
Oilseed rape	£190 /t	-	£447.0/ ha
Potatoes	£60 /t	-	£ 0.0/ ha
Harvesting and bagging potatoes	£15 /t	-	-

Table 4.1.5. Yields (t/ha) and fertiliser N applications (kg N/ha) and gross margins (GM, £/ ha) of crops receiving full-rate (CFP) inputs of fertiliser and agrochemicals.

a) Arable rotation

Year	*Phase I*				*Phase II*			
	Crop	Yield (t/ha)	Fert. N (kg/ha)	GM (£/ha)	Crop	Yield (t/ha)	Fert. N (kg/ha)	GM (£/ha)
1991	S. barley	6.4	40	683	S. barley	6.4	40	683
1992	Potatoes	42.8	150	1193	W.OSR	3.2	200	750
1993	W. wheat	3.9	130	256	W. wheat	6.5	130	548
1994	W. barley	7.2	150	664	S. barley	6.4	110	674
1995	W.OSR	3.3	150	843	Potatoes	40.0	150	1130
1996	W. barley	5.4	120	477	W. wheat	6.7	130	493
Mean	-	-	-	686	-	-	-	713

b) Arable/grass rotation

Year	*Phase I*				*Phase II*			
	Crop	Yield (t/ha)	Fert. N (kg/ha)	GM (£/ha)	Crop	Yield (t/ha)	Fert. N (kg/ha)	GM (£/ha)
1991	Grass	-	-		S. barley	6.4	40	683
1992	Potatoes	39.3	150	1034	W. barley	7.8	100	700
1993	W. wheat	3.6	110	218	Grass	-	-	
1994	S. barley	6.4	110	677	Grass	-	-	
1995	W. barley	7.5	160	656	Potatoes	38.9	120	1027
1996	Grass	-	-	-	W. wheat	8.1	130	631
Mean	-	-	-	646	-	-	-	760

c) Continuous spring barley

Year	Crop	Yield (t/ha)	Fert. N (kg/ha)	GM (£/ha)
1991	S. barley	6.4	40	683
1992	S. barley	5.1	80	561
1993	S. barley	5.4	80	577
1994	S. barley	5.4	110	576
1995	S. barley	5.3	110	505
1996	S. barley	5.1	110	464
Mean	-	-	-	561

W, Winter; S, Spring; OSR, Oilseed rape.

Table 4.1.6. Effects of reduced inputs for spring barley, winter barley and winter wheat, averaged over all rotations, on yield change (%) and gross margin change (GM, £/ha/year) when compared with the full-rate fertiliser CFP treatment. One unit of pesticide is taken to be one full-rate label-recommended treatment of one active ingredient.

Fertiliser	Pesticides	Spring Barley (6 crops)		Winter Barley (4 crops)		Winter Wheat (5 crops)	
		Yield change (%)	GM change (£/ha/year)	Yield change (%)	GM change (£/ha/year)	Yield change (%)	GM change (£/ha/year)
	All pesticides	Full rate pesticide units: 14		Full rate pesticide units: 14		Full rate pesticide units: 16	
Full rate	Half rate	- 1.6	+14	-0.7	+34	-4.3	+35
Half rate	Half rate	-16.3	-28	-19.8	-32	-23.6	-17
Half rate	Full rate	-18.7	-52	-15.4	-43	-23.2	-82
Half rate*	Integrated	-12.7	-20	-18.2	+36	-18.8	+25
None*	Minimum	-44.9	-85	-29.5	+25	-42.0	-17
	Herbicide	Full rate herbicide units: 11		Full rate herbicide units: 6		Full rate herbicide units: 6	
Full rate	Half rate	-3.2	- 2	+4.9	+46	-7.0	-13
Half rate	Half rate	-16.4	-26	-16.4	-39	-24.9	-64
Half rate*	Integrated	-12.0	-16	-5.4	+55	-20.2	-19
	Fungicide	Full rate fungicide units: 2		Full rate fungicide units: 6		Full rate fungicide units: 10	
Full rate	Half rate	+1.3	+12	+0.2	+24	-13.6	-42
Half rate	Half rate	-18.8	-51	-18.2	-41	-27.3	-65
Half rate*	Integrated	-7.0	-16	-6.8	+47	-18.8	-14
	Insecticide	Full rate insecticide units: 1		Full rate insecticide units: 2		Full rate insecticide units: 0	
Full rate	Half rate	+1.4	+7	+4.8	+35	-	-
Half rate	Half rate	-13.1	-31	-18.9	-63	-	-
Half rate*	Integrated	-14.6	-43	+6.3	+148	-	-

* Phase II Rotations only.

Table 4.1.7. Effects of reduced inputs for potatoes and oilseed rape, averaged over all rotations, on yield change (%) and gross margin (GM, £/ha/ year) when compared with the full-rate fertiliser CFP treatment. One unit of pesticide is taken to be one full-rate label-recommended treatment of one active ingredient.

Fertiliser	Pesticides	Oilseed rape (2 crops)		Potatoes (4 crops)	
		Yield change (%)	GM change (£/ha/year)	Yield change (%)	GM change (£ ha/year)
	All pesticides	Full rate pesticide units: 5		Full rate pesticide units: 42	
Full rate	Half rate	-17.1	-33	-12.5	-126
Half rate	Half rate	-38.9	-112	-29.9	-340
Half rate	Full rate	-20.9	-73	-13.9	-148
Half rate*	Integrated	-	-	-28.8	-325
None	Minimum*	-	-	-49.8	-547
	Herbicide	Full rate herbicide units: 4		Full rate herbicide units: 8	
Full rate	Half rate	-26.1	-101	-10.9	-150
Half rate	Half rate**	-40.2	-133	-23.8	-281
Half rate*	Integrated	-	-	-15.4	-142
	Fungicide	Full rate fungicide units: 0		Full rate fungicide units: 34	
Full rate	Half rate	-	-	-3.6	-14
Half rate	Half rate	-	-	-8.9	-169
Half rate*	Integrated	-	-	-7.0	-11
	Insecticide	Full rate insecticide units: 1		Full rate insecticide units: 0	
Full rate	Half rate	+2.0	+27	-	-
Half rate	Half rate	-21.3	-62	-	-
Half rate*	Integrated	-	-	-	-

* Phase II Rotations only. ** In the 1995 oilseed rape, no herbicide was applied to this treatment.

Table 4.1.8. Broad-leaved weed biomass (g/0.5 m^2) at harvest in the Arable Rotation Phase II from 1991 to 1996 and in selected years from other rotations.

Rotation and Crop	Full rate fertiliser		Half rate fertiliser		Nil fertiliser & herbicide	SEM 46 df
	Full rate herbicide	Half rate herbicide	Full rate herbicide	Half rate herbicide		
Arable Rotation, Phase II						
1991 Spring barley	14.3	20.5	9.0	17.9	23.2	3.02
1992 Winter OSR	40.9	57.3	17.4	27.3	38.0	6.33
1993 Winter wheat	1.8	2.1	1.8	2.5	27.9	15.23
1994 Spring barley	8.8	14.9	3.1	5.7	78.1	3.06
1995 Potatoes	41.0	178.0	81.0	208.0	256.0	53.57
1996 Winter wheat	3.4	15.1	2.3	7.0	22.8	3.71
Arable Rotation, Phase I						
1993 Winter wheat	15.8	48.8	28.9	109.8	-	31.42
1994 Winter barley	0.0	0.0	0.1	0.0	-	3.06
1995 Winter OSR	118.0	174.0*	100.0	245.0*	-	25.80
1996 Winter barley	5.8	5.9	9.5	19.0	-	3.21
Arable/Grass, Phase II						
1995 Potatoes	10.0	118.0	1.0	272.0	227.0	53.57
1996 Winter wheat	0.1	0.3	2.1	0.5	14.6	2.05

* No herbicide was applied to these plots. OSR = oilseed rape.

Table 4.1.9. Foliar disease in representative cereal crops from 1992 to 1996. Area of disease (% of leaf area) plus senescence on 2nd or 3rd leaf at last date of assessment for each crop.

Crop	Full rate fertiliser		Half rate fertiliser		Nil fertiliser & fungicide
	Full rate fungicide	Half rate fungicide	Full rate fungicide	Half rate fungicide	
1992 Winter barley	47.6	53.9	55.9	57.3	58.7
1993 Winter wheat	62.8	80.5	65.8	74.0	74.8
1994 Winter barley	2.8	2.1	2.1	2.0	-
1995 Winter barley	9.1	11.7	10.3	9.3	-
1996 Winter wheat	32.3	70.0	61.7	61.6	95.0

Table 4.1.10. Effect of potato seed treatment with metribuzin on subsequent plant and tuber fungal infections in 1992.

% infection	With fungicide[1]	Without fungicide	Significance value
Skin spot	0.6	4.3	$P < 0.05$
Common scab	5.0	7.2	Not significant
Black scurf	0.0	4.1	$P < 0.001$
Silver scurf	4.7	11.8	$P < 0.01$
Powdery scab	0.6	4.4	$P < 0.05$
Stolon canker	3.7	34.6	$P < 0.001$
Stem canker	7.5	77.5	$P < 0.001$

[1] Metribuzin.

Table 4.1.11. The effect on a two-year grass break on a) yield and b) gross margin of ware potato and winter wheat crops grown in the following two years.

a. Yield (t/ha)

Fertiliser	Pesticides	*1st year 1995 ware potatoes* Arable rotation	Grass rotation	Yield change (%)	*2nd year 1996 winter wheat* Arable rotation	Grass rotation	Yield change (%)
Full rate	Full rate (CFP)	40.0	38.9	-2.8	6.7	8.1	+20.9
Full rate	Half rate (LIA)	24.3	32.7	+34.6	6.3	7.4	+17.5
Half rate	Half rate (LIA)	22.1	23.5	+6.3	4.4	6.4	+45.5
Half rate	Full rate (CFP)	29.5	36.2	+22.7	4.0	6.0	+50.0
Half rate	Integrated (ILIA)	30.5	36.2	+18.7	3.8	5.7	+50.0
None	Minimum (MIN)	13.3	26.1	+96.2	3.3	5.1	+54.5

b. Gross margin (£/ha)

Fertiliser	Pesticides	*1st year 1995 ware potatoes* Arable rotation	Grass rotation	Yield change (£/ha)	*2nd year 1996 winter wheat* Arable rotation	Grass rotation	Yield change (£/ha)
Full rate	Full rate	1101	993	-108	493	631	+138
Full rate	Half rate	516	1145	+629	528	645	+117
Half rate	Half rate	488	531	+43	416	591	+175
Half rate	Full rate	657	1255	+598	297	481	+184
Half rate	Integrated	631	1075	+444	407	584	+177
None	Minimum	282	922	+640	460	639	+179

GM = gross margin.

Table 4.1.12. Number of carabid beetle species recorded in pitfall traps on the RISC site from May to August, 1992–1996.

Rotation	Arable Phase II	Arable Phase I	Arable /grass Phase II	Arable /grass Phase I	Cont. s. barley -	Field margin -	Total species
1992							
Crop	*W. OSR*	*Potatoes*	*W. barley*	*Potatoes*	*S. barley*	*Grass*	
CFP	17	13	16	15	14	27	32
LIA	14	12	19	19	na	na	na
ILIA	20	na	22	na	na	na	na
MIN	27	na	19	na	na	na	na
1993							
Crop	*W. wheat*	*W. wheat*	*Grass*	*W. wheat*	*S. barley*	*Grass*	
CFP	14	5	14	17	13	20	29
LIA	13	9	12	15	na	na	na
ILIA	7	na	17	na	na	na	na
MIN	16	na	9	na	na	na	na
1994							
Crop	*S. barley*	*W. barley*	*Grass*	*S. barley*	*S. barley*	*Grass*	
CFP	15	14	9	8	11	15	25
LIA	13	10	9	13	na	na	na
ILIA	14	na	12	na	na	na	na
MIN	11	na	7	na	na	na	na
1995							
Crop	*Potatoes*	*W. OSR*	*Potatoes*	*W. barley*	*S. barley*	*Grass*	
CFP	11	19	16	15	17	18	33
LIA	14	20	12	19	na	na	na
ILIA	13	na	13	na	na	na	na
MIN	7	na	11	na	na	na	na
1996							
Crop	*W. wheat*	*W. barley*	*W. wheat*	*Grass*	*S. barley*	*Grass*	
CFP	16	12	13	11	18	13	30
LIA	16	16	15	17	na	na	na
ILIA	10	na	14	na	na	na	na
MIN	17	na	16	na	na	na	na

W, Winter; S, Spring; OSR, Oilseed rape.

Table 4.1.13. Average weekly carabid beetle catch in pitfall traps on the RISC site from May to August, 1992–1996.

Rotation	**Arable Phase II**	**Arable Phase I**	**Arable /grass Phase II**	**Arable /grass Phase I**	**Cont. s. barley -**	**Field margin -**	**Total carabids**
1992							
Crop	*W. OSR*	*Potatoes*	*W. barley*	*Potatoes*	*S. barley*	*Grass*	
CFP	6.9	15.1	17.1	11.1	5.3	13.4	280.7
LIA	10.1	15.4	16.5	18.2	na	na	na
ILIA	8.4	na	27.8	na	na	na	na
MIN	60.8	na	23.5	na	na	na	na
1993							
Crop	*W. wheat*	*W. wheat*	*Grass*	*W. wheat*	*S. barley*	*Grass*	
CFP	10.5	3.8	12.5	7.9	8.9	8.5	150.8
LIA	9.0	3.3	13.3	7.9	na	na	na
ILIA	8.5	na	9.9	na	na	na	na
MIN	17.2	na	10.0	na	na	na	na
1994							
Crop	*S. barley*	*W. barley*	*Grass*	*S barley*	*S. barley*	*Grass*	
CFP	10.2	4.6	5.8	4.1	6.3	3.5	100.7
LIA	7.9	6.4	6.8	6.2	na	na	na
ILIA	9.0	na	6.8	na	na	na	na
MIN	11.2	na	3.8	na	na	na	na
1995							
Crop	*Potatoes*	*W. OSR*	*Potatoes*	*W. barley*	*S. barley*	*Grass*	
CFP	3.3	11.9	3.1	10.8	4.7	5.8	129.7
LIA	3.0	19.3	4.8	36.4	na	na	na
ILIA	1.8	na	4.5	na	na	na	na
MIN	2.1	na	4.8	na	na	na	na
1996							
Crop	*W. wheat*	*W. barley*	*W. wheat*	*Grass*	*S. barley*	*Grass*	
CFP	6.3	11.6	16.9	4.0	7.2	1.2	141.4
LIA	7.1	13.4	13.9	16.1	na	na	na
ILIA	4.6	na	17.8	na	na	na	na
MIN	5.1	na	13.6	na	na	na	na

W, Winter; S, Spring; OSR, Oilseed rape.

Table 4.1.14. The 24 most frequently recorded species of carabid beetle on the RISC site, 1992–1996.

Species	Average number	Description (Anderson, 1997)
Pterostichus melanarius	1048	Ubiquitous on agricultural land, in hedgerows, heaths, peatlands and on mountains. Prefers dense vegetation. Fairly hygrophilous. Summer breeder.
Trechus quadristriatus	265	Open, dry country with short vegetation.
Nebria brevicollis	151	Shaded habitats, favours intensely managed pasture. Autumn breeder with a high dispersal ability. DA 0 – 15%.
Agonum dorsale	140	Open countryside and grassland. Spring breeder. DA 0 – 15%.
Calathus melanocephalus	139	All kinds of open, moderately dry soil with grass or weedy vegetation. Autumn breeder. DA 0 – 15%.
Bembidion lampros	117	Dry, open habitat. Spring coloniser of arable fields.
Amara plebeja	105	Firm clay, often near water among grass, dense vegetation. Avoids high nitrogen fertilisers.
Bembidion tetracolum	100	Open, moderately moist habitat, a riverbank species. Pioneer colonisers preferring scattered vegetation of grasses and weeds.
Bembidion guttula	98	Found near fresh water on clay with rich vegetation. Also in shady places. Spring breeder.
Loricera pilicornis	68	Open countryside, moist weedy conditions, widespread, spring breeder. DA 0 – 15%.
Pterostichus niger	64	Not too dry soils.
Amara ovata	41	Open, rather dry, gravelly ground with sparse but often tall vegetation.
Pterostichus strenuus	32	Shady places, lowland areas.
Bembidion aeneum	29	Firm, moist clay with short vegetation.
Amara familiaris	28	All kinds of open ground, in meadows and waste places among weeds.
Bembidion unicolor	24	Moderately moist soil, amongst leaves and moss.
Agonum muelleri	22	Open clayish, moderately dry, often cultivated soil. High dispersal ability.
Bembidion bruxellense	17	Eurytopic, all kinds of moist ground with sparse vegetation, near water.
Carabus granulatus	13	Eurytopic, prefers wet areas. Spring breeder. DA 15 – 30%.
Amara similata	13	Open, moderately dry ground with cruciferous plants and other weeds.
Amara lunicollis	12	Meadows, gardens and on peaty soils.
Clivina fossor	11	Open, not too dry and more or less vegetated ground.
Notiophilus bigutattus	5	Shady, dry places.
Harpalus rufipes	4	Open, cultivated fields and on waste places.

DA = daylight activity; Eurytopic = wide habitat range.