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MANAGING EARLY-DRILLED SECOND WHEATS TO MINIMISE THE IMPACT OF TAKE-ALL

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MANAGING EARLY-DRILLED SECOND WHEATS TO MINIMISE THE IMPACT OF TAKE-ALL

by

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Contents

Abstract

Take-all is a major cause of economic loss in consecutive winter wheat crops. Correct husbandry has formed the basis for reducing its impact on yield, most importantly crop rotation and sowing date. Second-fourth wheats are at highest risk, and advice has been to delaying drilling these until October rather than sowing in September. As take-all damages the root system, other factors likely to restrict their growth or nutrient uptake must also be avoided. With a bigger area of wheat on farms, and a trend towards earlier drilling, the take-all risk has increased. Seed treatments have recently been developed which offer greater scope for take-all control, and their implications for sowing dates, seed rates and nitrogen management for second wheats were evaluated.

Two small plot trials series were sown at four contrasting sites and two target sowing dates (10th September and 10th October) in 1997/98, 1998/99 and1999/2000. The first compared three seed treatments, fludioxonil, fludioxonil + silthiofam, and fuberidazole + triadimenol, at three seed rates, 200, 300 and 400 seeds/m^2. The second series compared fludioxonil and fludioxonil + silthiofam with six nitrogen treatments, a total of 160 200 or 240 kg N/ha, with either 20% or 40% applied as an early dose. Plots were assessed for crop structure and yield component effects, and take-all incidence and severity, and trials were then taken to yield.

Drilling second wheats in September, rather than October, led to a doubling of the take-all incidence in April, a two-thirds increase in severity in June, and an average yield decrease of 0.9 t/ha. Adding silthiofam treatment to fludioxonil reduced take-all severity in April by 50%, giving an average yield increase of 0.46 t/ha when sown in September, but in excess of 1.5 t/ha where take-all was most damaging. Fuberidazole + triadimenol gave a 33% reduction, and a yield benefit of 0.36 t/ha. In October, increases were smaller averaging 0.20 t/ha with silthiofam (up to more than 1.0 t/ha), and no benefit from fuberidazole + triadimenol. Seed treatment did not alter the optimum seed rate at either sowing date. Take-all incidence in April was greater at the highest seed rate in some trials. Increasing the nitrogen fertiliser rate from 200 to 240 kg N/ha, and applying 40% rather than 20% early, increased yield regardless of sowing date or seed treatment, by an average of 0.59 t/ha.

Where take-all incidence is low on medium or heavy soils, September drilling using a take-all seed treatment can give equal or higher yields than for a standard treatment sown in October. However the treatments only gave partial control of take-all, and in general earlier sowing resulted in an economic loss and should be avoided. It is therefore essential to maintain all other husbandry practices which help to minimise its effects.

Summary

Introduction

Take-all (*Gaeumannomyces graminis* var. *tritici*) is a major cause of economic loss in consecutive crops of winter wheat. All soil types are potentially at risk, although crops grown on well-aerated light or organic soils, fertile silts and poorly drained clays are often worst affected. Those on well-structured clay soils tend to suffer less. Appropriate husbandry has formed a sound basis for minimising the impact of take-all on grain yield. Crop rotation is critical, as first wheats following a non-cereal break crop (or oats) rarely suffer significant damage. Sowing date is also crucial, with early-sown crops being at highest risk. Advice has therefore been to drill first wheats first, followed by continuous wheats (where take-all has begun to decline due to a build-up of antagonistic micro-organisms), and finally second-fourth wheats last of all. Good grassweed control is also important, as rhizomatous species such as couch can harbour the disease.

The main effect of take-all is damage to the root system. Therefore, it is vital to avoid other restrictions on root growth or nutrient uptake. This includes correcting pH, drainage or soil compaction problems, avoiding loose seedbeds, ensuring phosphate and other elements are not deficient, and applying adequate nitrogen fertiliser in early spring. The relationship between take-all and nitrogen is complex. High nitrate levels have been observed to increase take-all severity, although ammonium is thought to favour antagonistic bacteria (*Pseudomonads*).

As farm sizes have grown, and the proportion of wheat in rotations has risen, there has been a trend towards earlier drilling. For second or subsequent wheats, this has meant an increased take-all risk. Until recently, the only additional measure available has been use of a triadimenol-based seed treatment, which has shown some useful benefits against the disease. However autumn 2000 saw the approval of fluquinconazole (partnered by prochloraz), followed recently by silthiofam in 2001, both of which are intended specifically for take-all control. The main objectives of this project were to study the effects of drilling second wheats at an earlier timing, and to investigate the role that seed treatments might have in reducing the impact of take-all on yield. A further consideration was the possible effect of seed treatment on response to seed rate, as this would strongly influence the cost-benefit relationship. A final objective was to examine whether earlier sowing and seed treatment might alter the current advice for nitrogen fertiliser applications to crops at risk from take-all.

Methods

Replicated small plot trials were carried out at four contrasting locations in England during the 1997/1998, 1998/1999 and 1999/2000 seasons. These were Great Carlton in Lincolnshire (heavy fine clay loam prone to waterlogging), Wye in Kent (medium brickearth or silt loam soils), Kettering in Northamptonshire (heavy chalky boulder clay) and Cirencester in Gloucestershire (light limestone brash). Two trials series were sown

with Consort at two target sowing dates, 10th September and 10th October. The only significant departure from this was Wye in autumn 1999, when wet weather meant that sowing was delayed until early and late October.
The first trials series compared three seed treatments, fludioxonil (‘Beret Gold’), fludioxonil + silthiofam (‘Beret Gold’ plus ‘Latitude’) and fuberidazole + triadimenol (‘Baytan’), sown at three seed rates, 200, 300 and 400 seeds/m^2, all from a single batch of seed. Seed treatment application rates are shown in Table 1.

Table 1 Seed Treatment Application Rates

Active Ingredient (s)	Product (s)	Application Rate
fuberidazole + triadimenol	Baytan Flowable	4.5 + 37.5 g ai / 100 kg seed
fludioxonil	Beret Gold	5 g ai / 100 kg seed
fludioxonil + silthiofam	Beret Gold + Latitude	5 + 25 g ai / 100 kg seed

The second trials series evaluated two of the seed treatments, fludioxonil and fludioxonil + silthiofam, with six nitrogen treatments (Table 2), comprising three total application rates (160, 200 and 240 kg N/ha) and two split timings (20% or 40% as a first dose). A standard nitrogen programme (equivalent to treatment N3 in series two) was used in trials series one. A standard seed rate (400 seeds/m^2) was used in series two. A full programme of other crop protection inputs was applied, according to normal practice for each site.

Table 2 Nitrogen Fertiliser Treatments

Treatment Number	Nitrogen Fertiliser Applied (kg N/ha)		
	GS25-27 (early March)	GS30-31 (mid April)	Total Applied
N1	32	128	160
N2	64	96	160
N3	40	160	200
N4	80	120	200
N5	48	192	240
N6	96	144	240

Assessments carried out (some only on selected treatments) included autumn plant populations, spring shoot numbers and ear counts, all in marked quadrats, thousand grain weight measurements and the incidence of late-season whiteheads (as a percentage of each plot). Take-all necrosis on the roots was assessed in all trials at both GS31 and GS65. Both the incidence (number of plants affected) and severity (percentage of the root area infected) were recorded, and the latter was converted to a severity index (out of 100). All trials were taken to yield, except Great Carlton in 1998, where site variability was considered too high.

Trials were sown to a pre-determined layout, using a randomised split plot design in 1997, and a split split plot design in 1998 and 1999, with sowing date as the main plot, seed treatment as the sub-plot, and seed rate (series one) or nitrogen treatment (series two) as the sub-sub-plot. Four replicates were used to allow for the patchy nature of take-all occurrence. Trial designs and statistical analysis were provided by BioSS.

Results

Effects of Location and Sowing Date

In trials series one differences between years were relatively small, but grain yields differed substantially between sites. In 1999, Cirencester and Kettering produced their highest yields whereas Great Carlton and Wye gave their lowest. There were larger differences between years in series two, with all four locations producing their lowest yields in 1999. Averaged over all the seed treatments, the mean yield for the September sowing date in series one was 7.59 t/ha, compared to 8.17 t/ha for October. The yield decrease resulting from earlier drilling ranged from 0.29 t/ha in 1998 to 1.05 t/ha in 1999. The average yield reduction between the September and October sowing dates in series two was 0.96 t/ha, again highest in 1999 and lowest in 1998. In both trials series, Cirencester gave the biggest penalty with earlier drilling, and Great Carlton the smallest.

The incidence of take-all in April at GS31 was highest in 1999 and lowest in 1998. Severity in June at GS65 also peaked in 1999, but was lowest in 2000. Both incidence and severity were higher with September drilling than October (Table 3), especially in April. Levels of the disease tended to be lower on the heavy clay land at Great Carlton and Kettering than on the light/medium soils at Cirencester and Wye.

Table 3 Take-all Incidence and Severity (Mean of all Trials)

Season	Sowing Date	Incidence at GS31 (%)	Severity Index at GS65
1997/1998	September	24.2	20.3
	October	13.3	15.7
1998/1999	September	44.8	26.4
	October	19.6	13.0
1999/2000	September	42.2	13.2
	October	18.9	6.6

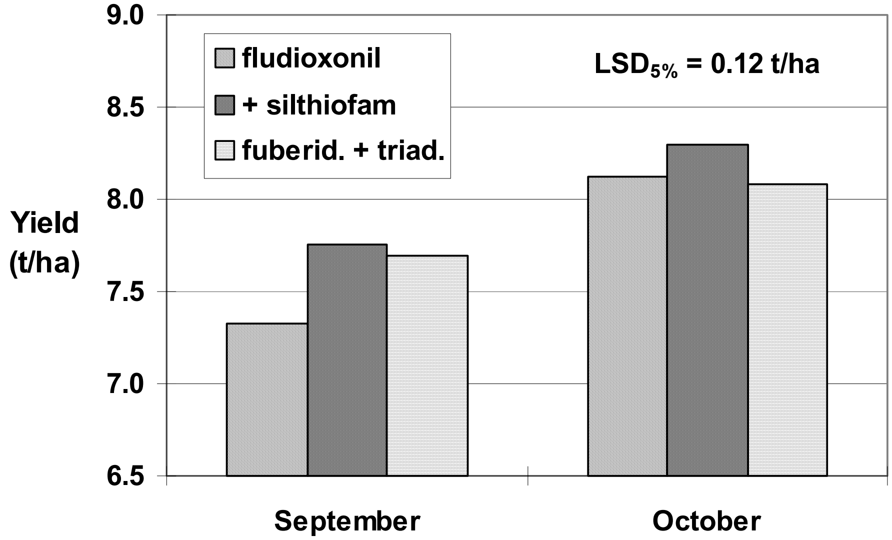
The average autumn plant populations obtained each year were similar, with October drilling generally resulting in slightly better establishment than September (66% compared to 61%). Sowing date had no consistent effects on shoot populations, but later drilling produced higher ear counts. The mean population for the October sowing date was 395 ears/m^2, compared to 373 ears/m^2 for September. In most cases, thousand grain weights were lower for the September sowing date than the October, by an average of 1.0g.

Effects of Seed Treatment

Over the three years in series one, the mean yield with fludioxonil + silthiofam seed treatment was 8.03 t/ha, compared to 7.73 t/ha with fludioxonil alone. The yield of fuberidazole + triadimenol was 7.89 t/ha. Both gave a significant yield increase over fludioxonil when sown in September, but only silthiofam gave a benefit with October drilling (Figure 1). Although average yield responses to silthiofam were only 0.43 t/ha and 0.18 t/ha respectively, they ranged from +0.04 to +1.75 t/ha for September sowing, and -0.34 to +0.81 t/ha for October.

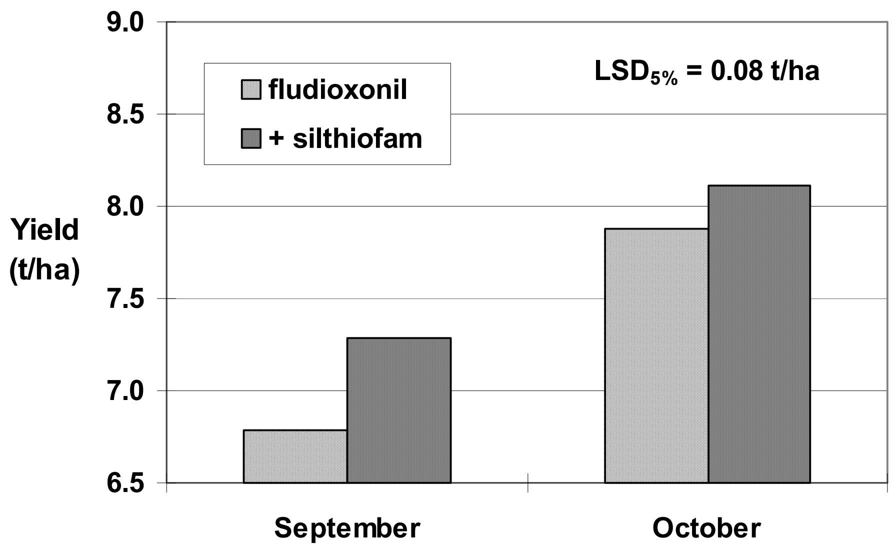
The average yield drop from October-sown fludioxonil to September-sown fludioxonil + silthiofam was 0.36 t/ha, and only in two out of eleven trials did the latter combination give higher yields.

Figure 1 Effect of Sowing Date and Seed Treatment on Grain Yield - Series One, Mean of all Trials



In series two, the mean yield for fludioxonil alone was 7.34 t/ha compared to 7.70 t/ha with silthiofam, an increase of 0.49 t/ha when sown in September and 0.23 t/ha in October (Figure 2). However, as in series one the response range was wide for both sowing dates (-0.15 to +1.49 t/ha and -0.11 to +1.31 t/ha respectively).

Figure 2 Effect of Sowing Date and Seed Treatment on Grain Yield - Series Two, Mean of all Trials



In all three seasons, seed treatment had a significant effect on the incidence and severity of take-all at GS31 in April. Compared to fludioxonil alone, the addition of silthiofam reduced average severity by about 50%, whereas fuberidazole + triadimenol gave a reduction of about 33%. There was a similar pattern at GS65 in June, with an average reduction of 30% with silthiofam, but only 15% with fuberidazole + triadimenol.

The greatest differences occurred in the 1998/1999 season (see Table 4), when take-all was at its worst. The incidence of whiteheads reflected this, with fludioxonil showing an average of 21%, fludioxonil + silthiofam 12% and fuberidazole + triadimenol 17% ($LSD_{5\%}$ = 2.1). Assessment for other stem base diseases revealed that eyespot in particular was present, but there were no apparent differences between seed treatments.

Table 4 Effects of Sowing Date and Seed Treatment on Take-all Severity (Series One, 4 Site Mean)

Target Sow Date	Seed Treatment(s)	1998/1999 Season		Three Year Mean	
		GS31 Index	GS65 Index	GS31 Index	GS65 Index
10 September	fludioxonil	11.12	31.3	8.43	23.0
	fludioxonil + silthiofam	4.85	17.9	4.38	16.9
	fuberidazole + triadimenol	7.33	22.9	5.56	19.9
10 October	fludioxonil	4.65	14.9	3.40	14.2
	fludioxonil + silthiofam	1.82	9.7	1.37	8.8
	fuberidazole + triadimenol	3.01	11.0	2.50	11.5
LSD 5%		1.67	3.9	-	-

There were no differences in plant or shoot populations between fludioxonil and fludioxonil + silthiofam. Fuberidazole + triadimenol gave significantly lower plant populations, particularly when sown in October on the heavy land sites. Despite having slightly more shoots per plant in some cases, it also gave lower shoot populations (Table 5). However there were no differences in ear populations, except in 1998/1999 when fludioxonil + silthiofam had a higher population than both the other two seed treatments. In 1997/1998 and 1999/2000, fuberidazole + triadimenol compensated by producing a higher number of ears per plant.

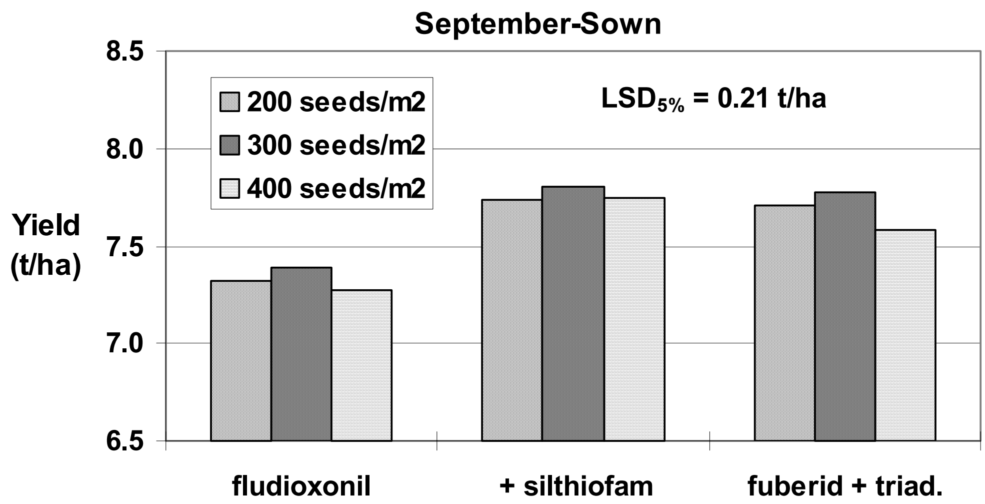
Table 5 Effects of Seed Treatment on Plant, Shoot and Ear Populations (Series One, 4 Site Mean)

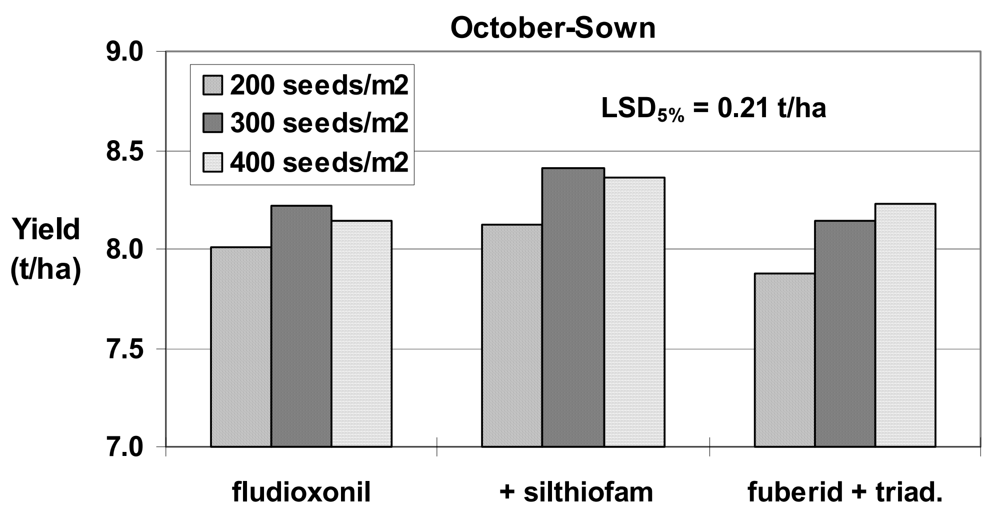
Season	Population	fludioxonil	fludioxonil + silthiofam	fuberidazole + triadimenol	LSD 5%
1997/1998	Plants/m^2	173	176	160	8.0
	Shoots/m^2	563	561	526	20
	Ears/m^2	334	335	333	n.s.
1998/1999	Plants/m^2	210	212	193	8.1
	Shoots/m^2	664	668	623	22
	Ears/m^2	375	388	373	12
1999/2000	Plants/m^2	201	200	185	6.2
	Shoots/m^2	633	641	617	21
	Ears/m^2	420	421	426	n.s.

Seed Rate Response

Overall the highest yielding seed rate at both sowing dates was 300 seeds/m^2, although the yield reduction at 200 seeds/m^2 was small, especially with September drilling. There were no significant differences between seed treatments (see Figure 3). However, there tended to be a smaller yield penalty from 400 seeds/m^2 with fludioxonil + silthiofam than with the other two seed treatments when sown in September. With October drilling, only fuberidazole + triadimenol gave a higher yield at 400 seeds/m^2 than at 300 seeds/m^2.

Figure 3 Effects of Sowing Date, Seed Treatment and Seed Rate on Grain Yield - Mean of all Trials





In 1999 and 2000, the incidence of take-all in April at GS31 was higher at 400 seeds/m^2 than at 200 seeds/m^2. However, there were no differences in 1998 (see Table 6). The only difference at GS65 was with fludioxonil seed treatment in 1999, when take-all was more severe at 400 than at 200 seeds/m^2. The number of ears per plant decreased with increasing seed rate in all years, but ear populations still increased (Table 6):

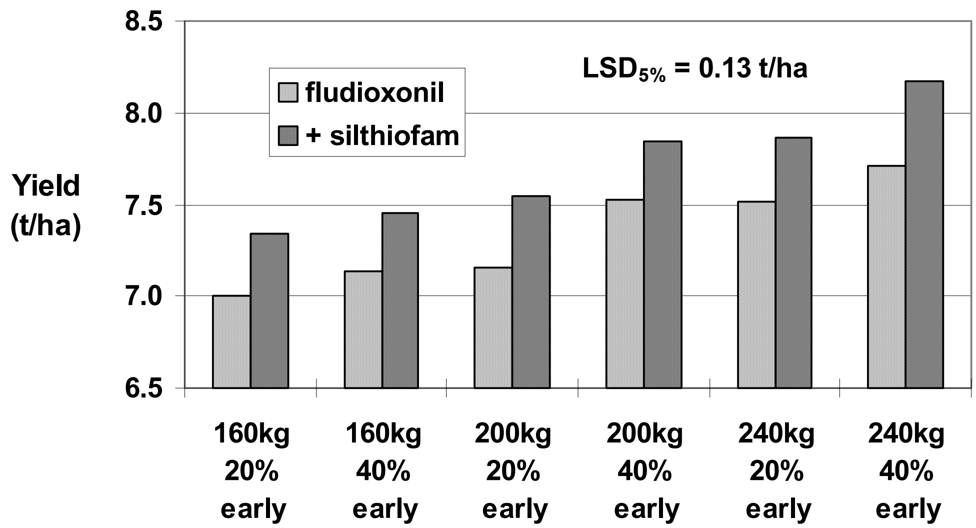
Table 6 Effects of Seed Rate on Take-all Incidence and Ear Populations (Series One, 4 Site Mean)

Assessment	Year	Seed Rate (seeds/m^2)			LSD 5%
		200	300	400	
% Incidence of Take-all at GS31	1998	17.9	-	18.5	n.s.
	1999	27.9	-	34.0	3.58
	2000	27.7	-	32.6	2.63
Ear Populations per m^2	1998	325	335	340	14.5
	1999	364	380	392	12.3
	2000	400	428	438	8.1

Interaction with Nitrogen Treatment

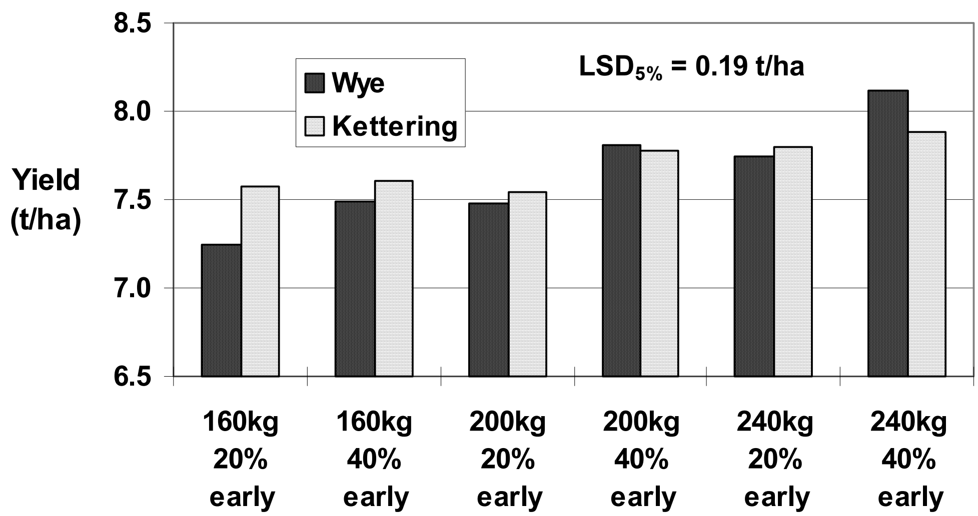
Nitrogen treatment had a significant effect on yield in all three years, and neither seed treatment nor sowing date affected this (Figure 4). The average yield increase between the application rates of 160 and 200 kg N/ha was 0.29 t/ha (4%), and between 200 and 240 kg N/ha it was 0.30 kg/ha (4%). The average yield benefit from applying 40% rather than 20% of the total dose early (at mid-late tillering) was 0.24 t/ha (3%).

Figure 4 Effect of Seed Treatment on Yield Response to Nitrogen Treatment - Mean of all Trials



Not all sites gave the same magnitude of response to nitrogen treatment. The difference between the highest and lowest yielding treatments averaged 14% at Great Carlton, 12% at Wye and Cirencester, and only 4% at Kettering (Figure 5). With the exception of Great Carlton, where the response to a larger early dose was small, applying 40% rather than 20% early gave a similar yield benefit to a 40 kg N/ha increase in total rate.

Figure 5 Effect of Location on Yield Response to Nitrogen Treatment - Three Year Mean



In 1998 and 1999, there was a tendency for take-all severity to be lower at GS65 where 40% of the nitrogen had been applied early, although differences were not significant. At GS31, severity was either increased or unaffected as a result of applying the higher early nitrogen dose. Nitrogen had no effect in 2000 (Table 7).

Table 7 Effects of Nitrogen and Seed Treatment on Take-all Severity (Series Two, 4 Site Mean)

Year	Seed Treatment	Severity Index at GS31		Severity Index at GS65	
		200, 20% early	200, 40% early	200, 20% early	200, 40% early
1999	fludioxonil	8.24	9.45	29.7	24.8
	+ silthiofam	3.08	4.38	18.2	12.6
	Mean	5.66	6.92	24.0	18.7
3 Year Mean	fludioxonil	5.63	6.08	21.5	18.4
	+ silthiofam	3.24	3.36	13.3	11.1
	Mean	4.44	4.72	17.4	14.8

LSD 5% 1999 Mean = 0.50 (GS31), 14.3 (GS65)

Economic Analysis

The per hectare cost of a seed treatment depends on the extra cost per tonne for the seed, and the seed rate used. Using approximate prices in autumn 2000 as an example (fuberidazole + triadimenol £90/t, fludioxonil £45/t), and for a thousand grain weight of 50g, the difference between these two would have been £4.50-9.00 per hectare, depending on seed rate. At 200 seeds/m^2, the yield increase with fuberidazole + triadimenol sown in September was 0.39 t/ha, worth £23-29/ha for a grain price of £60-75/t. At 400 seeds/m^2, the benefit was 0.31 t/ha, worth £19-23/ha. In both cases, changing treatment was cost-effective. With a few exceptions, when sown in October fuberidazole + triadimenol did not give a yield benefit and would not have been cost-effective.

The cost of silthiofam is not yet known, but for illustration a value of £180/t (combined with fludioxonil) has been assumed. In trials series one, at 200 seeds/m^2 the yield increase from adding silthiofam was 0.42 t/ha when sown in September, worth £25-32/ha. At 400 seeds/m^2, the extra yield was 0.48 t/ha worth £29-36/ha. Both would have been cost-effective. With average increases of only 0.11 t/ha at 200 seeds/m^2 and 0.22 t/ha at 400 seeds/m^2, in general silthiofam treatment would not have been justified when sown in October. However there were exceptions, Wye in 1998 and 1999, Great Carlton in 1999 and 2000, and Cirencester in 2000.

Table 8 Margin over Cost of Treated Seed (£/ha) - Mean of all series one trials.

Target Sow Date	Seed Treatment(s)	Margin over cost £/ha (grain £60/t)			Margin over cost £/ha (grain £75/t)		
		200 seeds	300 seeds	400 seeds	200 seeds	300 seeds	400 seeds
10 September	fludioxonil	417	410	391	527	521	500
	+ silthiofam	428	414	393	545	531	509
	fuberid + triadim	436	426	401	551	543	515
10 October	fludioxonil	458	459	443	578	583	566
	+ silthiofam	451	451	430	573	577	555
	fuberid + triadim	446	448	440	564	570	563

The margin per hectare over the cost of treated seed for each sowing date, seed treatment and rate is shown in Table 8. An untreated seed cost of £180/t has been assumed. Of the seed rates examined, the optimum for September sowing was 200 seeds/m^2, whereas for October there was little difference between 200 and 300 seeds/m^2. There was no economic advantage from September drilling, regardless of seed treatment or rate.

In series two, the average yield increase with silthiofam in September was 0.49 t/ha, worth £29-37/ha. With fludioxonil alone, the benefit from increasing the total nitrogen rate from 200 to 240 kg N/ha, and applying 40% rather than 20% early, was 0.67 t/ha, worth £40-50/ha. Combining silthiofam seed treatment with the changed nitrogen strategy, the mean yield increase was 1.07 t/ha, worth £70-88/ha. Subtracting the cost of the extra nitrogen fertiliser (£14/ha at £0.35 per kg N) would leave £56-74/ha before the cost of the silthiofam. Sown in October, the combined increase was 0.85 t/ha, worth £37-50/ha after deducting the extra nitrogen.

Conclusions

Advancing the drilling of second wheats from mid October to mid September is likely to increase take-all and reduce grain yield. With fludioxonil seed treatment alone, the incidence of take-all in April was doubled, and severity in June was increased by two-thirds. As a consequence, yields were reduced by an average of 0.9 t/ha.

Seed treatments can be used to give partial control of take-all. Using fuberidazole + triadimenol, severity was reduced by 33% in April, whilst adding silthiofam to a standard treatment (fludioxonil) led to a reduction of 50%. The effects of both treatments diminished with time, and by June differences were smaller. When sown in mid September, the average yield increase through changing seed treatment was 0.36 t/ha with fuberidazole + triadimenol, and 0.46 t/ha from the addition of silthiofam. Larger increases, in excess of 1.5 t/ha, were obtained where take-all levels were high on more susceptible soil types. In general, fuberidazole + triadimenol did not give a yield increase when sown in October, and the benefit from silthiofam was smaller at 0.20 t/ha. However, increases in excess of 1.0 t/ha were still obtained where take-all was most damaging.

Excluding normal adjustments for sowing date, seedbed conditions and soil type, seed rates do not need to be altered as a result of using silthiofam in addition to a standard seed treatment. In these trials, there were no differences in establishment, tillering, shoots surviving to produce ears, or the optimum seed rate, at either sowing date. In contrast, fuberidazole + triadimenol often produced lower plant and shoot populations, especially when sown on heavy land in October. Although this tended not to reduce ear populations, in a few cases the optimum seed rate for yield was higher than with fludioxonil. There was evidence of a higher take-all incidence in April at the highest seed rate, but only in one case (with fludioxonil) was severity greater in June.

Adopting an appropriate nitrogen fertiliser strategy is vital for second wheat crops at risk from take-all. This includes applying a sufficiently high total rate, and a large enough first dose. Applying an extra 40kg N/ha above the site standard, and 40% rather than 20% of the total at the early timing, improved yield by 0.59 t/ha. Sowing in September rather than October, and use of the take-all seed treatment, did not diminish the yield benefit obtained by altering the nitrogen strategy. There was some indication of a link between the proportion of nitrogen applied early and levels of take-all, but the effects were small and not always detrimental.

The treatments evaluated were not intended to identify the optimum nitrogen rate for second wheats, which must take into account factors such as soil type, soil nitrogen supply and crop use. It would also be wrong to conclude that the highest early dose used here (96 kg /ha) should routinely be applied. Increased lodging risk and foliar disease pressure might otherwise occur. However, where take-all is a risk, a modest increase above the 40 kg N/ha typically applied at tillering would be beneficial where the main dose is not applied until April.

Implications

Where the take-all incidence is low, on medium or heavy soils, September drilling using a seed treatment with take-all activity can give equal or higher yields than for a standard treatment sown in October. This is unlikely to be the case on lighter soils or where early season take-all levels are high. In general, the treatments studied here only partly compensated for the effects of early sowing, so advancing the drilling of second wheats from mid October to mid September is still likely to result in an economic loss and should be avoided if possible.

If September drilling is unavoidable, a seed treatment with take-all activity should routinely be considered for second wheats. Both fuberidazole + triadimenol and silthiofam are suitable. Depending on the price of silthiofam treatment, fuberidazole + triadimenol could be the more appropriate under average conditions, but silthiofam has given better control of take-all and larger yield responses. Fuberidazole + triadimenol is less suited to October sowing, and use of silthiofam will not be justified as often as in September. Nevertheless, it could still be worthwhile for high risk sites. The magnitude of the yield increase with silthiofam appears to be related to the incidence of take-all in early spring. If the latter could be predicted in the autumn prior to sowing, then use of the seed treatment could be better targeted.

Higher seed rates than normal are not required to maintain the benefits of silthiofam seed treatment, and may be detrimental through increased take-all incidence. The optimum seed rate will therefore be the same as for the standard seed treatment on its own, when sown under the same conditions. Additional evaluation of the interaction between seed treatments, seed rates and take-all is now taking place.

Even where a specific seed treatment is used, as take-all control is only partial, it is essential to maintain all other husbandry practices which help to minimise the effects of the disease, whether drilling in September or in October. This includes applying adequate nitrogen fertiliser, with a large enough first dose.

The Effects of Seed Treatment on Responses to Sowing Date and Seed Rate, and the Impact of Take-all on Grain Yield, in Second Wheats.

1. Introduction

The importance of take-all (*Gaeumannomyces graminis* var. *tritici*) as a cause of yield loss in consecutive winter wheat crops has long been recognised. Up to 50% of the wheat area is at risk, with losses of 20-50% possible (Hornby D, Bateman GL, 1991). Most farm cropping sequences are planned specifically to avoid the disease. First wheats after a non-cereal (or oat) break rarely suffer significant levels, although poor control of cereal volunteers or rhizomatous grassweeds such as couch can reduce the effectiveness of a break. Various husbandry practices are known to help minimise the effects of take-all. These are beneficial because they help to avoid further restrictions on root growth and uptake, which is the main damage caused by the disease. They include correcting drainage, soil structure or pH problems, avoiding loose seedbeds, and ensuring that the soil is not deficient in phosphate or other elements (MAFF, 1986). Work by ARC and others has also confirmed the importance of early spring nitrogen fertiliser, to compensate for poor uptake resulting from root damage.

Sowing date is also critical in determining the level of take-all. Early drilling increases exposure to inoculum, and provides more favourable conditions for infection. Advice has been to drill first wheats after a break first, followed by continuous wheat (where take-all is in decline due to a build-up of antagonistic micro-organisms), and finally second-fourth wheats which are at highest risk (MAFF, 1986). However, as farm sizes have grown and the proportion of wheat in rotations has risen, there has been a trend towards earlier drilling, in order to avoid the practical problems associated with later sowing. The ability to sow second or subsequent wheats earlier has taken on new significance with the development of seed treatments which offer scope for the control of take-all. In previous years, this has sometimes been achieved by using a triadimenol-based seed treatment (Bateman, 1986). However autumn 2000 saw the approval of ‘Jockey’ (fluquinconazole + prochloraz), followed recently by ‘Latitude’ (silthiofam) in 2001, both of which are intended specifically for this purpose.

The main objectives of this research were to study the implications of advancing second wheat drilling, to an earlier first wheat timing, and to investigate the extent to which seed treatments might facilitate this by reducing the impact of take-all on grain yield. A further objective was to examine the effects of seed treatment on response to seed rate at early and conventional sowing dates. This is of particular importance because take-all seed treatments are likely to add considerably to the cost of the seed. A final objective of the project, which is covered in the accompanying paper, was to determine whether applying early spring nitrogen was still as important for second wheats which are drilled earlier and with a take-all seed treatment. The trials reported here have been restricted to the evaluation of the seed treatment silthiofam. However, further work is taking place to provide comparable results for fluquinconazole + prochloraz, and this will be reported separately.

2. Materials and Methods

2.1 Overview

Replicated small plot trials were carried out at four contrasting locations in England during the 1997/1998, 1998/99 and 1999/2000 seasons. In this trials series (series one), the winter wheat variety Consort was drilled following wheat at two target sowing dates (10th September and 10th October), using three seed rates (200, 300 and 400 seeds/m^2) and three seed treatments (fludioxonil, fludioxonil + silthiofam, and fuberidazole + triadimenol), in a pre-determined split plot design. A standard nitrogen fertiliser dose was applied (40 kg N/ha at GS25-27 in early March and 160 kg N/ha at GS31 in mid April), and crop protection inputs were used according to normal practice for each site. Plant, shoot and ear populations, root infection with take-all, and incidence of whiteheads were assessed. Grain yields were determined using a plot combine, and samples taken for physical analysis. Results were then subjected to analysis of variance.

2.2 Site Details and Sowing Dates

The four locations, their soil types, and the sowing dates achieved in each season, are shown in Table 2.1. In general, trials were drilled within 1 week of their target date. The only significant departure from this was in the South in autumn 1999, when wet weather meant that both drilling dates were delayed until October.

Table 2.1 Site Details and Sowing Dates

Location	Soil Type	Actual Sowing Dates		
		1997/98	1998/99	1999/2000
North - Great Carlton (Lincolnshire)	heavy fine clay loam	22 September 8 October	18 September 12 October	18 September 6 October
South - Wye (Kent)	medium brickearth / silt loam	11 September 14 October	11 September 19 October	7 October 27 October
East - Kettering (Northamptonshire)	heavy chalky boulder clay	11 September 9 October	14 September 16 October	17 September 14 October
West - Cirencester (Gloucestershire)	light limestone brash	10 September 9 October	11 September 16 October	13 September 15 October

2.3 Seed Treatment Details

Application rates for the three seed treatments examined are shown in Table 2.2. A single batch of Consort seed was used for all three treatments (and all four sites) each year. The seed for each plot was individually weighed, packeted and drilled to achieve the desired seed rates of 200, 300 and 400 seeds/m^2.

Table 2.2 Seed Treatment Application Rates

Active Ingredient (s)	Product (s)	Application Rate
fuberidazole + triadimenol	Baytan Flowable	4.5 + 37.5 g ai / 100 kg seed
fludioxonil	Beret Gold	5 g ai / 100 kg seed
fludioxonil + silthiofam	Beret Gold + Latitude	5 + 25 g ai / 100 kg seed

2.4 Assessment Details

Autumn plant population was determined for all treatments at GS13 by counting 6 x 1.0m row lengths per plot (4 of which were in marked areas). Spring shoot counts were carried out on 4 x 1.0m rows per plot at the end of GS30 in the same marked areas. The number of shoots per plant was then able to be calculated. Ear populations were determined pre-harvest by counting 6 x 1.0m rows per plot (4 in the marked areas), and the number of ears per plant then calculated.

Root infection with take-all was assessed at a minimum of two timings, April (at GS31) and June (at GS65), at the 200 and 400 seeds/m^2 seed rates only. At each timing, 4 x 0.25m row lengths were dug at random from each plot, avoiding the outside rows. Roots were then washed after excess soil had been removed. Both the incidence (number of plants affected) and severity (percentage of root area affected) of take-all necrosis were recorded. A take-all severity index was then calculated (see appendix A). The incidence of whiteheads was scored at GS77 for each treatment as a percentage of the whole plot. Levels of other potential causal agents (eyespot and Fusarium species) were also noted. Fresh grain yields were determined using a plot combine, and these were adjusted for moisture content and plot size to give a yield in tonnes/ha at 15% moisture content. Specific weight (kg/hl) and thousand grain weight (g) were measured from each plot sample.

2.5 Trial Design and Statistical Analysis

Each year, trials were sown to a pre-determined layout. In 1997/1998 a randomised split plot design was used, with sowing date as the main plot and seed treatment x seed rate as the sub plot. In the second and third years, a randomised split-split plot design was used to allow more accurate comparisons, with sowing date as the main plot, seed treatment as the sub-plot, and seed rate as the sub-sub-plot. Four replicates were used to allow for the patchy nature of take-all occurrence. Analysis of variance was carried out on all data, with a cross-site comparison for key results each year, and an over-year analysis for grain yield at the end of the final year.

3. Results

The results from the series one trials over three seasons are divided into three areas: 3.1 - Grain Yield, 3.2 - Crop Structure and Yield Components, and 3.3 - Take-all Severity and Whitehead Incidence.

3.1 Grain Yield

Grain yield data are presented in sub-sections 3.1.1 - 3.1.4 as follows:
3.1.1 - 1997/1998 season, 3.1.2 - 1998/1999 season, 3.1.3 - 1999/2000 season, and 3.1.4 - over-year analysis. No yields were recorded at Great Carlton in 1997/1998 due to site variability, and therefore the mean figures in the over-year analysis have been adjusted.

3.1.1 1997/1998 Season

For the three sites that were taken to yield in all three seasons, 1997/1998 gave the highest September-sown yields, and the smallest yield penalty from September drilling compared to October. The average yield of the September sowing was 7.46 t/ha, compared to 7.75 t/ha for October ($P < 0.001$). Fludioxonil + silthiofam gave a mean yield of 7.71 t/ha, compared to 7.52 t/ha for fludioxonil alone, and 7.58 t/ha for fuberidazole + triadimenol ($P = 0.055$). These were the smallest differences between seed treatments obtained over the three seasons. As Table 3.1 shows, both fludioxonil + silthiofam and fuberidazole + triadimenol gave a significant yield benefit when sown in September, but not in October:

Table 3.1 1997/1998 Grain Yield Responses to Sowing Date and Seed Treatment

Target Sow Date	Seed Treatment(s)	Grain Yield (t/ha)				
		G Carlton	Wye	Kettering	Cirencester	Site Mean
10 September	fludioxonil	-	7.81	7.65	6.32	7.26
	fludioxonil + silthiofam	-	8.26	7.94	6.45	7.55
	fuberidazole + triadimenol	-	8.01	8.37	6.36	7.58
10 October	fludioxonil	-	8.07	8.22	7.06	7.78
	fludioxonil + silthiofam	-	8.59	7.88	7.14	7.87
	fuberidazole + triadimenol	-	8.14	7.83	6.79	7.59
F prob. sed. (d.f.)		- -	0.799 0.434 (4.3)	0.034 0.449 (5.7)	0.591 0.231 (18.2)	0.014 0.094 (8.0)

Seed rate had a significant effect on yield at Wye ($P = 0.026$), and overall ($P = 0.008$). The highest yielding seed rate was 300 seeds/m^2 when sown in September and 400 seeds/m^2 in October. The seed rate responses of fludioxonil and fludioxonil + silthiofam were very similar for both drilling dates. However, fuberidazole + triadimenol drilled at 400 seeds/m^2 showed a penalty when sown in September, and a benefit when sown in October (see Table 3.2), notably for the heavy land site at Kettering.

Table 3.2 1997/1998 Grain Yield Response to Seed Rate (3 Site Mean)

Target Sow Date	Seed Treatment(s)	Grain Yield (t/ha)		
		200 seeds/m^2	300 seeds/m^2	400 seeds/m^2
10 September	fludioxonil	7.13	7.34	7.30
	fludioxonil + silthiofam	7.39	7.69	7.57
	fuberidazole + triadimenol	7.68	7.68	7.37
10 October	fludioxonil	7.62	7.88	7.85
	fludioxonil + silthiofam	7.73	7.92	7.96
	fuberidazole + triadimenol	7.08	7.69	8.00
F prob. sed. (d.f.)		0.034 0.162 (8)		

3.1.2 1998/1999 Season

The highest yields at Cirencester and Kettering were obtained in 1999. This season saw the largest yield penalty from drilling in September rather than October, and the biggest difference between seed treatments. The average yield of the September sowing was 7.35 t/ha, compared to 8.40 t/ha for October (P <0.001). Overall fludioxonil + silthiofam gave a mean yield of 8.10 t/ha, compared to 7.58 t/ha for fludioxonil, and 7.94 t/ha for fuberidazole + triadimenol (P <0.001). Responses to seed treatment differed between locations, but the four site mean showed a significant yield increase with fludioxonil + silthiofam and fuberidazole + triadimenol compared to fludioxonil alone, when sown in September. With October drilling, only fludioxonil + silthiofam gave a yield increase:

Table 3.3 1998/1999 Grain Yield Responses to Sowing Date and Seed Treatment

Target Sow Date	Seed Treatment(s)	Grain Yield (t/ha)				
		G Carlton	Wye	Kettering	Cirencester	Site Mean
10 September	fludioxonil	9.36	5.24	7.29	5.58	6.86
	fludioxonil + silthiofam	9.40	6.99	8.26	6.08	7.68
	fuberidazole + triadimenol	9.34	6.51	7.74	6.47	7.52
10 October	fludioxonil	8.83	7.37	9.10	7.90	8.30
	fludioxonil + silthiofam	9.15	8.18	9.09	7.68	8.53
	fuberidazole + triadimenol	9.15	7.58	9.06	7.65	8.36
F prob. sed. (d.f.)		0.348 0.169 (12)	0.115 0.361 (12)	0.388 0.482 (12)	0.469 0.646 (12)	<0.001 0.079 (12)

Seed rate had a significant effect on yield at Great Carlton (P = 0.003) and at Wye (P = 0.014), where there was a yield penalty from 400 seeds/m^2 when sown in September. In most cases the highest yielding seed rate was 200 seeds/m^2 when sown in September and 300 seeds/m^2 in October. Seed treatment had little effect on response to seed rate at either sowing date, although fludioxonil showed the largest penalty at 400 seeds/m^2 when sown in September (Table 3.4):

Table 3.4 1998/1999 Grain Yield Response to Seed Rate (4 Site Mean)

Target Sow Date	Seed Treatment(s)	Grain Yield (t/ha)		
		200 seeds/m^2	300 seeds/m^2	400 seeds/m^2
10 September	fludioxonil	7.03	6.94	6.62
	fludioxonil + silthiofam	7.65	7.61	7.78
	fuberidazole + triadimenol	7.61	7.50	7.44
10 October	fludioxonil	8.27	8.42	8.21
	fludioxonil + silthiofam	8.38	8.66	8.54
	fuberidazole + triadimenol	8.27	8.43	8.38
F prob. sed. (d.f.)		0.612 0.137 (12)		

3.1.3 1999/2000 Season

The lowest overall yields from the three years were recorded in 2000, with an average of 7.38 t/ha from September sowing and 7.97 t/ha from October (P <0.001). Fludioxonil + silthiofam gave a mean yield of 7.84 t/ha, compared to 7.55 t/ha for fludioxonil alone, and 7.64 t/ha for fuberidazole + triadimenol (P <0.001). At Cirencester, fludioxonil + silthiofam gave a significant yield increase compared to fludioxonil or fuberidazole + triadimenol, whereas at Great Carlton both fludioxonil + silthiofam and fuberidazole + triadimenol gave a yield increase over fludioxonil. The four site mean showed a significant interaction between sowing date and seed treatment (see Table 3.5).

Table 3.5 1999/2000 Grain Yield Responses to Sowing Date and Seed Treatment

Target Sow Date	Seed Treatment(s)	Grain Yield (t/ha)				
		G Carlton	Wye	Kettering	Cirencester	Site Mean
10 September	fludioxonil	8.41	7.06	7.67	5.59	7.18
	fludioxonil + silthiofam	9.13	7.33	7.80	5.95	7.55
	fuberidazole + triadimenol	8.90	7.13	7.93	5.68	7.41
10 October	fludioxonil	9.44	7.59	8.54	6.12	7.92
	fludioxonil + silthiofam	9.69	7.66	8.72	6.45	8.13
	fuberidazole + triadimenol	9.67	7.18	8.50	6.11	7.86
F prob. sed. (d.f.)		0.076 0.132 (12)	0.494 0.281 (12)	0.475 0.217 (12)	0.825 0.116 (12)	0.035 0.068 (12)

Seed rate had a significant effect on yield at Great Carlton (P = 0.015) and Kettering (P = 0.016). Overall, there was a yield penalty from sowing 400 seeds/m^2 in September or 200 seeds/m^2 in October. Seed treatment had little effect on response to seed rate at either sowing date (Table 3.6):

Table 3.6 1999/2000 Grain Yield Response to Seed Rate (4 Site Mean)

Target Sow Date	Seed Treatment(s)	Grain Yield (t/ha)		
		200 seeds/m^2	300 seeds/m^2	400 seeds/m^2
10 September	fludioxonil	7.26	7.23	7.05
	fludioxonil + silthiofam	7.57	7.64	7.45
	fuberidazole + triadimenol	7.41	7.55	7.28
10 October	fludioxonil	7.75	8.04	7.98
	fludioxonil + silthiofam	7.92	8.28	8.19
	fuberidazole + triadimenol	7.78	7.87	7.95
F prob. sed. (d.f.)		0.538 0.117 (12)		

3.1.4 Over-Year Analysis

Over the three seasons, the mean grain yield from September drilling was 7.59 t/ha compared to 8.17 t/ha from October, a penalty of 0.58 t/ha (P<0.001). The average yield with fludioxonil + silthiofam seed treatment was 8.03 t/ha, compared to 7.73 t/ha with fludioxonil, a benefit of 0.30 t/ha (P <0.001). The yield of fuberidazole + triadimenol was intermediate at 7.89 t/ha. However, as Table 3.7 shows, both alternatives gave a significant advantage over fludioxonil-alone when sown in September:

Table 3.7 Grain Yield Responses to Sowing Date and Seed Treatment - Over-Year Analysis

Target Sow Date	Seed Treatment(s)	Grain Yield (t/ha)				
		G Carlton	Wye	Kettering	Cirencester	Site Mean
10 September	fludioxonil	8.89	6.80	7.54	5.83	7.33
	fludioxonil + silthiofam	9.26	7.46	8.00	6.16	7.76
	fuberidazole + triadimenol	9.12	7.24	8.01	6.17	7.69
10 October	fludioxonil	9.14	7.71	8.62	7.03	8.12
	fludioxonil + silthiofam	9.42	8.14	8.56	7.09	8.30
	fuberidazole + triadimenol	9.41	7.65	8.47	6.85	8.08
F prob. sed. (d.f.)		0.404 0.063 (4)	0.170 0.168 (8)	0.003 0.093 (8)	0.025 0.105 (8)	<0.001 0.060 (80)

Seed rate had a significant effect on yield (P = 0.001). The highest yielding seed rate at both sowing dates was 300 seeds/m^2, although the penalty at 200 seeds/m^2 was small, especially with September sowing. There were no significant differences between seed treatments. There was however an indication of a smaller penalty from 400 seeds/m^2 sown in September with fludioxonil + silthiofam compared to the other two treatments, and a greater benefit from 400 seeds/m^2 in October with fuberidazole + triadimenol (Table 3.8):

Table 3.8 Grain Yield Response to Seed Rate (Site Mean) - Over-Year Analysis

Target Sow Date	Seed Treatment(s)	Grain Yield (t/ha)		
		200 seeds/m^2	300 seeds/m^2	400 seeds/m^2
10 September	fludioxonil	7.32	7.39	7.27
	fludioxonil + silthiofam	7.74	7.80	7.75
	fuberidazole + triadimenol	7.71	7.78	7.58
10 October	fludioxonil	8.01	8.22	8.14
	fludioxonil + silthiofam	8.12	8.41	8.36
	fuberidazole + triadimenol	7.88	8.14	8.23
F prob. sed. (d.f.)		0.543 0.104 (80)		

3.2 Crop Structure and Yield Components

Results from the plant, shoot and ear population counts, and thousand grain weight measurements, for each of the seasons are presented in sub-sections 3.2.1 - 3.2.3, with a summary in 3.2.4.

3.2.1 1997/1998 Season

Plant populations increased with seed rate at all sites, producing an average of 131, 160 and 191 plants/m^2 from 200, 300 and 400 seeds/m^2 respectively when sown in September, and 136, 180 and 220 plants/m^2 sown in October. Only Kettering gave higher populations from September drilling. Fuberidazole + triadimenol gave the lowest populations, averaging 160 plants/m^2, compared to 173 and 176 plants/m^2 for the other two seed treatments (P = 0.002). These differences were greatest on the heavy land sites at Great Carlton and Kettering.

The number of shoots per plant decreased with increasing seed rate (from an average of 3.7 at 200 seeds/m^2 to 3.0 at 400 seeds/m^2), but seed treatment had little effect. Shoot populations followed a similar pattern to plant populations (Table 3.9):

Table 3.9 Effect of Seed Treatment and Seed Rate on Shoot Populations per m^2 (4 Site Mean)

Treatment	fuberidazole + triadimenol	fludioxonil	fludioxonil + silthiofam	Mean
200 seeds/m^2	454	475	486	472
300 seeds/m^2	549	590	577	572
400 seeds/m^2	574	625	622	607
Mean	526	563	561	F prob. <0.001
	F prob. 0.002 sed. 9.3 (d.f.) 12			sed. 9.3 (d.f.) 12

The number of ears per plant decreased with increasing seed rate (Table 3.10), and fuberidazole + triadimenol had a higher number than the other two seed treatments. There were no significant differences in final ear population between seed rates or seed treatments. However, the average ear population at the four locations ranged from 179 ears/m^2 at Great Carlton up to 459 ears/m^2 at Kettering.

Table 3.10 Effect of Seed Treatment and Seed Rate on Number of Ears per Plant (4 Site Mean)

Treatment	fuberidazole + triadimenol	fludioxonil	fludioxonil + silthiofam	Mean
200 seeds/m^2	2.68	2.34	2.43	2.48
300 seeds/m^2	2.18	2.02	1.91	2.04
400 seeds/m^2	1.78	1.68	1.62	1.70
Mean	2.21	2.02	1.99	F prob. <0.001
	F prob. 0.006 sed. 0.062 (d.f.) 12			sed. 0.062 (df) 12

Both sowing date and seed treatment had an effect on thousand grain weight. The average for September drilling was 46.3g, compared to 47.5g for October (P = 0.002). The average for fludioxonil + silthiofam was 47.3g, compared to 46.9g for fuberidazole + triadimenol and 46.3g for fludioxonil (P = 0.066).

3.2.2 1998/1999 Season

Plant populations increased with seed rate at all sites, producing an average of 143, 198 and 245 plants/m^2 from 200, 300 and 400 seeds/m^2 respectively when sown in September, and 144, 217 and 281 plants/m^2 sown in October. Only Cirencester gave higher populations from drilling in September than October. Fuberidazole + triadimenol gave the lowest populations, averaging 193 plants/m^2, compared to 210 and 212 plants/m^2 for the other two seed treatments (P <0.001). These differences were greatest on the heavy land site at Great Carlton.

The number of shoots per plant decreased with increasing seed rate (from an average of 4.1 at 200 seeds/m^2 to 2.8 at 400 seeds/m^2). Fuberidazole + triadimenol had a slightly higher number (3.5) than the other two seed treatments (3.3). However, this difference was not significant and shoot populations reflected the differences in plant populations (Table 3.11):

Table 3.11 Effect of Location and Seed Treatment on Shoot Populations per m^2 (Mean of 3 Seed Rates)

Treatment	**fuberidazole + triadimenol**	**fludioxonil**	**fludioxonil + silthiofam**	F prob. sed. (d.f.)
Great Carlton	513	554	546	0.134 19.7 (12)
Wye	653	643	644	0.937 29.7 (12)
Kettering	906	1044	1067	0.009 46.1 (12)
Cirencester	422	415	414	0.947 25.1 (12)
Mean	623	664	668	0.002 10.2 (12)

The number of ears per plant decreased with increasing seed rate, from 2.6 ears/plant at 200 seeds/m^2 to 1.5 ears/plant at 400 seeds/m^2. Overall, there was a small but significant increase in the ear population with increasing seed rate, and there were also differences between seed treatments. (see Table 3.12).

Table 3.12 Effect of Location and Seed Treatment on Ear Populations per m^2 (Mean of 3 Seed Rates)

Treatment	**fuberidazole + triadimenol**	**fludioxonil**	**fludioxonil + silthiofam**	F prob. sed. (d.f.)
Great Carlton	305	313	310	0.768 12.1 (12)
Wye	377	371	409	0.054 14.7 (12)
Kettering	468	492	500	0.029 10.7 (12)
Cirencester	343	323	335	0.189 10.3 (12)
Mean	373	375	388	0.039 5.6 (12)

Both sowing date and seed treatment had a significant effect on thousand grain weight. The average for September drilling was 45.8g, compared to 47.5g for October (P <0.001). The averages for fludioxonil + silthiofam and fuberidazole + triadimenol were 47.1g and 47.2g respectively, compared to 45.7g for fludioxonil (P <0.001).

3.2.3 1999/2000 Season

Plant populations increased with seed rate at all sites, producing an average of 141, 197 and 244 plants/m^2 from 200, 300 and 400 seeds/m^2 respectively when sown in September, and 145, 199 and 246 plants/m^2 sown in October. Only Wye gave higher populations at the earlier sowing date (note that in 1999 the two drilling dates were delayed to early and late October at this location). Fuberidazole + triadimenol gave the lowest populations, averaging 185 plants/m^2, compared to 201 and 200 plants/m^2 for the other treatments (P <0.001). This difference occurred at all four sites in 1999/2000.

The number of shoots per plant decreased with increasing seed rate (from an average of 4.1 at 200 seeds/m^2 to 2.9 at 400 seeds/m^2). Fuberidazole + triadimenol had a slightly higher number (3.6) than either fludioxonil + silthiofam (3.5) or fludioxonil alone (3.4), and the latter difference was significant (P = 0.005). At three locations, fludioxonil + silthiofam recorded higher shoot populations than the other two seed treatments. The exception to this was Kettering (Table 3.13):

Table 3.13 Effect of Location and Seed Treatment on Shoot Populations per m^2 (Mean of 3 Seed Rates)

Treatment	fuberidazole + triadimenol	fludioxonil	fludioxonil + silthiofam	F prob. sed. (d.f.)
Great Carlton	512	530	541	0.402 20.7 (12)
Wye	755	770	796	0.098 17.3 (12)
Kettering	781	805	772	0.391 24.1 (12)
Cirencester	419	430	454	0.025 11.1 (12)
Mean	617	633	641	0.075 9.6 (12)

The number of ears per plant decreased with increasing seed rate, but there was an increase in ear population from 400 ears/m^2 at 200 seeds/m^2 to 438 ears/m^2 at 400 seeds/m^2 (P <0.001). Fuberidazole + triadimenol had a higher number of ears per plant (see Table 3.14), but seed treatment had little effect on final ear populations:

Table 3.14 Effect of Seed Treatment and Seed Rate on Number of Ears per Plant (4 Site Mean)

Treatment	fuberidazole + triadimenol	fludioxonil	fludioxonil + silthiofam	Mean
200 seeds/m^2	3.03	2.79	2.89	2.90
300 seeds/m^2	2.42	2.16	2.19	2.26
400 seeds/m^2	1.99	1.80	1.80	1.86
Mean	2.48	2.25	2.29	F prob. <0.001 sed. 0.027 (df) 12
	F prob. <0.001 sed. 0.027 (d.f.) 12			

Sowing date had a significant effect on thousand grain weight. The average for September drilling was 46.3g, compared to 45.7g for October (P <0.001). There were no significant differences between seed treatments.

3.2.4 Summary

Plant populations were similar over the three years of trials, with October drilling leading to slightly higher populations than September in most cases. Fuberidazole + triadimenol consistently gave lower populations (an average of 179 plants/m^2) than the other two treatments (195 and 196 plants/m^2). Seed treatment had relatively little effect on the number of shoots per plant, and although fuberidazole + triadimenol tended to have marginally more, its shoot populations were usually lower. The effects of seed treatment on ear populations were small compared to seed rate and the overwhelming effects of location. In 1998 and 1999, thousand grain weights were lower with September drilling and fludioxonil seed treatment, but this was not the case in 2000.

3.3 Take-all Severity and Whitehead Incidence

Results from the root take-all assessments at GS31 in April and GS65 in June, and the late season whitehead incidence, are presented for each of the years in sub-sections 3.3.1 - 3.3.3, with a summary in 3.3.4. Take-all assessments were carried out at the highest and lowest seed rates (200 and 400 seeds/m^2) only.

3.3.1 1997/1998 Season

The proportion of plants with take-all necrosis on their roots averaged 18% at GS31 and 45% at GS65. Levels were highest at Wye and lowest at Great Carlton. At GS31, there was a significant difference between sowing dates (P <0.001), with 25% affected in the September drilled but only 11% in the October. By GS65, there was little difference. However, take-all severity was significantly lower for the later sowing at both assessment stages, with an index at GS65 of 23.4 for September compared to 16.5 for October (P = 0.005). Seed treatment also had an effect on take-all levels, and this was significant at GS31 (Table 3.15). Fludioxonil + silthiofam had a lower incidence and severity than fludioxonil, with fuberidazole + triadimenol intermediate. By GS65, fludioxonil + silthiofam was still lower, but differences between the other two treatments were small. Seed rate had no significant effect on take-all incidence or severity.

Table 3.15 Effects of Sowing Date and Seed Treatment on Take-all (4 Site Mean)

Target Sow Date	Seed Treatment(s)	% Incidence at GS31	Severity Index at GS31	% Incidence at GS65	Severity Index at GS65
10 September	fludioxonil	29.3	8.38	49.1	23.7
	fludioxonil + silthiofam	20.8	4.09	45.0	22.1
	fuberidazole + triadimenol	25.8	4.62	45.1	24.5
10 October	fludioxonil	16.8	3.21	44.6	20.4
	fludioxonil + silthiofam	5.9	0.80	36.3	11.5
	fuberidazole + triadimenol	10.5	2.25	48.8	17.6
Mean	fludioxonil	23.1	5.79	46.8	22.0
	fludioxonil + silthiofam	13.4	2.45	40.7	16.8
	fuberidazole + triadimenol	18.2	3.43	47.0	21.0
F prob. sed. (d.f.)		0.005 1.82 (6)	0.003 0.574 (8)	0.077 2.53 (6)	0.081 1.98 (6)

3.3.2 1998/1999 Season

The proportion of plants with take-all necrosis on their roots averaged 31% at GS31 and 59% at GS65. Levels were highest at Wye and lowest at Great Carlton. At both timings, there were significant differences between sowing dates (P <0.001). At GS31, 39% of plants were affected in the September drilled but only 23% in the October drilled. Take-all severity was also significantly lower for the later sowing at both assessment stages, with an index of 24.0 for September compared to 11.9 for October (P <0.001) at GS65. Seed treatment had a significant effect on take-all levels at both GS31 and GS65. At GS31, fludioxonil + silthiofam had a lower incidence and severity than fludioxonil, with fuberidazole + triadimenol intermediate. By GS65, differences in incidence were relatively small, but the pattern of severity remained the same (see Table 3.16).

Table 3.16 Effects of Sowing Date and Seed Treatment on Take-all (4 Site Mean)

Target Sow Date	Seed Treatment(s)	% Incidence at GS31	Severity Index at GS31	% Incidence at GS65	Severity Index at GS65
10 September	fludioxonil	45.3	11.12	71.5	31.3
	fludioxonil + silthiofam	33.4	4.85	65.0	17.9
	fuberidazole + triadimenol	39.4	7.33	70.8	22.9
10 October	fludioxonil	26.4	4.65	52.7	14.9
	fludioxonil + silthiofam	16.2	1.82	46.3	9.7
	fuberidazole + triadimenol	25.1	3.01	50.1	11.0
Mean	fludioxonil	35.8	7.88	62.1	23.1
	fludioxonil + silthiofam	24.8	3.34	55.7	13.8
	fuberidazole + triadimenol	32.2	5.17	60.4	17.0
F prob. sed. (d.f.)		0.002 1.72 (6)	<0.001 0.482 (6)	0.149 2.90 (6)	<0.001 1.14 (6)

At GS31, the incidence of take-all was higher at 400 seeds/m^2 than at 200 seeds/m^2, except at Great Carlton which had least take-all. However, by GS65 this difference was only apparent with fludioxonil seed treatment:

Table 3.17 Effect of Seed Rate on % Take-all Incidence at GS31 (Mean of all Seed Treatments)

Treatment	200 Seeds/m^2	400 Seeds/m^2	F prob.	sed. (d.f.)
Great Carlton	11.0	10.5	0.787	2.06 (18)
Wye, Kent	58.4	70.2	0.008	3.94 (18)
Kettering	18.6	22.6	0.069	2.03 (18)
Cirencester	23.5	32.9	0.054	4.52 (18)
Mean	27.9	34.0	0.005	1.41 (6)

At three out of four sites (the exception was Cirencester), the incidence of whiteheads at GS77 was highest with fludioxonil seed treatment, and lowest with fludioxonil + silthiofam (Table 3.18). Assessment for other stem-base diseases revealed that eyespot in particular was present, but there were no apparent differences between seed treatments.

Table 3.18 Effect of Location and Seed Treatment on % Incidence of Whiteheads

Treatment	fuberidazole + triadimenol	fludioxonil	fludioxonil + silthiofam	F prob. sed. (d.f.)
Great Carlton	15.5	21.0	8.0	0.059 4.89 (12)
Wye	25.7	31.6	17.2	0.051 5.21 (12)
Kettering	17.5	22.4	14.0	0.273 4.96 (12)
4 Site Mean	16.8	20.8	11.9	<0.001 0.94 (12)

3.3.3 1999/2000 Season

The proportion of plants showing root take-all averaged 30% at GS31 and 51% at GS65. Levels were highest at Cirencester and lowest at Kettering. At both GS31and GS65, there were differences between sowing dates. At GS31, 41% of plants were affected in the September drilled compared to 19% in the October. Take-all severity was also significantly lower for the later sowing at both assessment stages, with an index of 12.4 for September but only 6.2 for October (P <0.001) at GS65. Seed treatment had a significant effect on take-all levels at GS31 and GS65. At both GS31 and GS65, fludioxonil + silthiofam had a lower incidence and severity than fludioxonil, with fuberidazole + triadimenol intermediate (Table 3.19). Both the incidence and severity of take-all at GS31 increased with seed rate at all sites. The average incidence at 200 seeds/m^2 was 27.7% compared to 32.6% at 400 seeds/m^2 (P = 0.004). By GS65, no differences were apparent.

Table 3.19 Effects of Sowing Date and Seed Treatment on Take-all (4 Site Mean)

Target Sow Date	Seed Treatment(s)	% Incidence at GS31	Severity Index at GS31	% Incidence at GS65	Severity Index at GS65
10 September	fludioxonil	46.6	5.80	63.5	14.1
	fludioxonil + silthiofam	36.8	4.20	57.0	10.7
	fuberidazole + triadimenol	39.3	4.74	58.7	12.4
10 October	fludioxonil	21.7	2.33	49.3	7.2
	fludioxonil + silthiofam	15.0	1.50	37.2	5.3
	fuberidazole + triadimenol	21.5	2.23	40.1	6.0
Mean	fludioxonil	34.2	4.07	56.4	10.7
	fludioxonil + silthiofam	25.9	2.85	47.1	8.0
	fuberidazole + triadimenol	30.4	3.48	49.4	9.2
F prob. sed. (d.f.)		0.002 1.32 (6)	0.003 0.201 (6)	0.002 1.51 (6)	0.023 0.69 (6)

3.3.4 Summary

Take-all incidence was highest in 1999 and lowest in 1998, but late season severity was least in 2000. Levels tended to be lower on the heavy land at Kettering and Great Carlton than on the lighter soils at Cirencester and Wye. Both incidence and severity were higher in the September drilled than the October, especially at GS31. Levels of take-all were consistently lowest with fludioxonil + silthiofam seed treatment and highest with fludioxonil alone, notably at GS31. Fuberidazole + triadimenol was intermediate. Although seed rate had no effect in 1998, in the next two seasons take-all incidence at GS31 was higher at 400 than at 200 seeds/m^2.

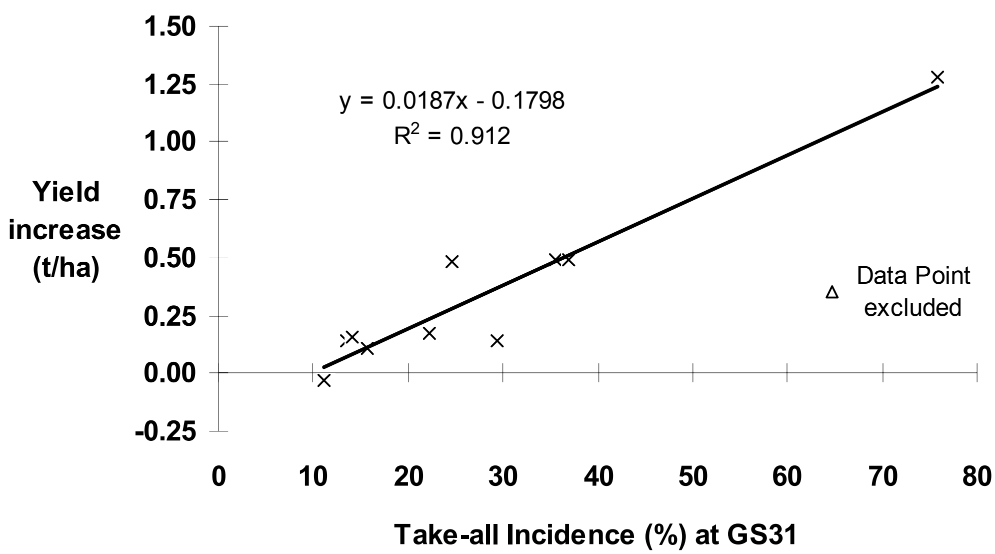
4. Discussion

4.1 Grain Yield

Later drilling of second and subsequent wheats has been the front-line measure to reduce the impact of take-all on yield. In these trials, the average penalty from September sowing compared to October using the standard fludioxonil seed treatment was 0.79 t/ha, which confirms that it is still very important. This penalty was nearly halved (to 0.43 t/ha) by changing the seed treatment to fuberidazole + triadimenol for September sowing, so advice to use this where earlier drilling is unavoidable has also been correct. At the same time, when sown in October there was often no advantage from fuberidazole + triadimenol. By adding silthiofam, the yield drop with September sowing was reduced to 0.36 t/ha compared to October-sown fludioxonil, but there was still a benefit (0.54 t/ha) from drilling it later. Only in 2 out of 11 trials (Wye in 1998 and Great Carlton in 1999) were the yields of September-sown fludioxonil + silthiofam higher than October-sown fludioxonil.

The mean advantage of fludioxonil + silthiofam over fludioxonil alone was only 0.18 t/ha when both were sown in October, compared to 0.43 t/ha in September. However, these average figures include a wide range of responses, from -0.34 t/ha to +0.81 t/ha when drilled in October, and from +0.04 to +1.75 t/ha in September.
The average yield response also differed between the four locations, ranging from 0.33 t/ha at Cirencester to 0.66 t/ha in Wye (when sown in September). It might be anticipated that for each trial the magnitude of the yield response to silthiofam would reflect the level of take-all. There was some correlation between average yield increase from adding silthiofam, and the incidence of take-all at GS31 with fludioxonil seed treatment ($R^2 = 0.67$), but this was improved by excluding the 1999/2000 trial at Cirencester, as shown in Figure 1.

Figure 1 Relationship between Take-all at GS31 and Yield Response to silthiofam



4.2 Economic Analysis

It is important to consider whether the yield increases obtained with either of the alternative seed treatments would have been sufficient to cover their extra cost compared to fludioxonil alone. The per hectare cost of a seed treatment depends on the additional cost per tonne for the treated seed, and the seed rate used. Table 4.1 shows how this might vary according to these two factors. A thousand grain weight of 50g has been assumed:

Table 4.1 Effect of Seed Treatment Cost per Tonne and Seed Rate on Cost per Hectare

Seed Rate	Seed Treatment Cost £/hectare			
(seeds/m2)	**£45/t**	**£90/t**	**£135/t**	**£180/t**
100	2.25	4.50	6.75	9.00
200	4.50	9.00	13.50	18.00
300	6.75	13.50	20.25	27.00
400	9.00	18.00	27.00	36.00

Using approximate prices in autumn 2000 for illustration, the cost of fludioxonil seed treatment would be close to £45/t, whereas fuberidazole + triadimenol would be nearer to £90/t. At the lowest seed rate (200 seeds/m^2), the average yield benefit with fuberidazole + triadimenol compared to fludioxonil when sown in September was 0.39 t/ha. For a grain price range of £60-75 per tonne, this would be worth £23-29 per hectare, making it cost-effective. At 400 seeds/m^2, the yield benefit was 0.31 t/ha, worth £19-23/ha. Again, this would have more than covered the extra £9/ha cost of the seed treatment. When sown in October, fuberidazole + triadimenol did not give consistent yield benefits and in general would not have been cost effective at either seed rate, except at Wye in 1999 and Great Carlton in 1999 and 2000.

The cost of silthiofam treatment is not yet known, but for illustration a value of £135/t will be assumed, giving a combined cost when added to fludioxonil of £180/t. At 200 seeds/m^2, the average yield increase from adding silthiofam to fludioxonil when sown in September was 0.42 t/ha, worth £25-32/ha. At 400 seeds/m^2, the increase was 0.48 t/ha, worth £29-£36/ha. Based on these values it would have been cost-effective at both seed rates, but only just at 400 seeds/m^2 if the lowest grain price were to apply. When sown in October, the average yield benefit was 0.11 t/ha at 200 seeds/m^2 and 0.22 t/ha at 400 seeds/m^2, which would not have been sufficient to cover the extra seed treatment cost calculated here. However, there were several exceptions, namely Wye in 1998 and 1999, Great Carlton in 1999 and 2000 (400 seeds/m^2 only) and Cirencester in 2000 (200 seeds/m^2 only), where the yield increases would have covered the extra cost.

Using these values, and an untreated seed cost of £180 per tonne, the margin per hectare over the cost of the treated seed can be calculated for each of the sowing dates, seed treatments and seed rates (see appendix D). These are summarised in Table 4.2.

Table 4.2 Margin over Cost of Treated Seed (£/ha) - Mean of all trials.

Target Sow Date	Seed Treatment(s)	Margin over cost £/ha (grain £60/t)			Margin over cost £/ha (grain £75/t)		
		200 seeds	300 seeds	400 seeds	200 seeds	300 seeds	400 seeds
10 September	fludioxonil	417	410	391	527	521	500
	+ silthiofam	428	414	393	545	531	509
	fuberid + triadim	436	426	401	551	543	515
10 October	fludioxonil	458	459	443	578	583	566
	+ silthiofam	451	451	430	573	577	555
	fuberid + triadim	446	448	440	564	570	563

Of the seed rates examined, the optimum for September sowing was 200 seeds/m^2, regardless of seed treatment or grain price. When sown in October, there was little or no difference between 200 and 300 seeds/m^2 for any of the seed treatments at a grain price of £60/t, but 300 seeds/m^2 was optimum for all three at a grain price of £75/t. There was no economic advantage from September sowing regardless of the seed treatment, seed rate or grain price. Based on the yield responses and seed treatment costs used in this illustration, it is apparent that fuberidazole + triadimenol could be more cost-effective than fludioxonil + silthiofam in the September-sown situation. However, it should be remembered that the range of responses was wide, and overall the benefits from fludioxonil + silthiofam were more consistent.

4.3 Crop Structure, Yield Components and the Severity of Take-all

Whilst both seed rate and trial location had significant effects, there were no differences between the seed treatments fludioxonil and fludioxonil + silthiofam in either plant or shoot populations, and only small differences in ear populations (in 1999). This contrasts with fuberidazole + triadimenol, which consistently gave lower plant populations, but partly compensated for this with a higher number of shoots per plant, and in most cases fully compensated for this by having more ears per plant. There was no indication that silthiofam seed treatment was altering the optimum seed rate in either September (typically 200 seeds/m^2) or October (typically 300 seeds/m^2). In most cases, fuberidazole + triadimenol also had the same optimum seed rate due to compensation, but occasionally a higher rate gave an advantage when sown in October.

With little or no recorded difference in ear populations between seed treatments (except in 1999 when take-all was most severe), the yield increases obtained over fludioxonil should have been reflected in either the number of grains per ear or the thousand grain weight for each treatment. Grains per ear were not measured, but thousand grain weight did show small increases with fuberidazole + triadimenol or the addition of silthiofam in 1998 and 1999, which were consistent with the yield effects. Later sowing also gave a higher thousand grain weight in all three years, again consistent with yields.

When the sites were selected for these trials, they were chosen to be representative of the range of soil types where second wheats might be grown in England. They were not selected because they necessarily had a history of take-all. Weather conditions during all three seasons of trials were favourable for the development of the disease, especially in 1999. Relatively wet autumns were followed by mild winters and then further dull, wet weather during April. As a result, all sites had at least some take-all present. However, in many cases the final severity would have been classed as low or moderate. Copious summer rainfall also helped alleviate potential moisture stress, and whiteheads caused by premature ripening were most obvious in 1999.

September sowing resulted in higher levels of take-all on the roots than October sowing. This is further confirmation of the need to delay drilling in the autumn. The differences in disease levels were greater at GS31 in April than at GS65 in June. However, take-all which develops early in the growing season is likely to have a greater affect on the crop than that which develops subsequently, as it is these infections which are most likely to damage the root stele and affect the ability to take up water and nutrients from the soil. Seed treatment had an affect on both the recorded incidence and severity of take-all, with the differences again greater at GS31 in April than at GS65 in June. A reduction in the incidence of the disease might not have been anticipated, although this may simply have come about due to plants being recorded as free from take-all where the severity was very low and not easily seen.

Fludioxonil + silthiofam gave a bigger decrease in root take-all levels than fuberidazole + triadimenol. At GS31, the former gave an average reduction in severity of about 50%, compared to 33% for the latter. At GS65, the reduction with fludioxonil + silthiofam averaged 30%, compared to only 15% with fuberidazole + triadimenol. These reductions in severity were obtained whether drilled in September or in October, but in most cases take-all levels were higher for fludioxonil + silthiofam sown in September than for fludioxonil alone sown in October. This helps to explain why use of the seed treatment does not fully recover the yield lost when sowing is brought forward to September.

There was no evidence that the reduction in take-all severity obtained with silthiofam seed treatment was greater or less at 400 seeds/m^2 than at 200 seeds/m^2. However, there was an indication in both 1999 and 2000 that the incidence of take-all at GS31 was higher at 400 seeds/m^2 than at 200 seeds/m^2. High seed rates have previously been suggested to favour the disease, due to increased root density. Therefore, although the addition of silthiofam to fludioxonil did not alter the optimum seed rate, this may explain why the penalty from drilling 400 seeds/m^2 in September was less than for fludioxonil alone. Additional trials were undertaken in autumn 2000 to further investigate the relationship between seed treatment, seed rate and take-all.

5. Conclusions and Implications

Advancing the drilling of second wheats from mid October to mid September is likely to increase take-all and reduce grain yield. In this trials series, with fludioxonil seed treatment alone, the visible incidence of take-all in April was doubled, and severity in June was increased by two-thirds. As a consequence, yields were reduced by an average of about 0.8 t/ha.

Using fuberidazole + triadimenol seed treatment, the severity of take-all in April was reduced by a third, whilst adding silthiofam to a standard treatment (in this case fludioxonil) reduced it by half. The effects of both appear to diminish with time, such that by June differences are smaller. The average yield increase through changing seed treatment for a second wheat sown in September was relatively small (only 0.36 t/ha with the use of fuberidazole + triadimenol, and 0.43 t/ha from the addition of silthiofam). However, as these trials have shown, much larger yield increases (in excess of 1.5 t/ha) are possible where take-all levels are high on more susceptible soil types. The magnitude of the yield increase with silthiofam appears to be related to the incidence of take-all in early spring. If the latter could be predicted in the autumn prior to sowing, then use of the seed treatment could be better targeted.

Where the early season incidence of take-all is low, on medium or heavy soils, it is possible to obtain equal or higher yields by adding silthiofam and sowing in September, compared to a standard seed treatment sown in October. However, this is not the case on lighter soils, or where take-all levels are high. The seed treatments examined here only partly compensated for the effects of early sowing, and therefore in general advancing drilling to mid September is still likely to result in an economic loss and should be avoided wherever possible.

If September drilling is unavoidable, a seed treatment with take-all activity should routinely be considered for second wheats. Both fuberidazole + triadimenol and silthiofam are suitable, and on average would have been cost-effective compared to the standard seed treatment alone (based on the values assumed here). Depending on the price of silthiofam-treated seed, fuberidazole + triadimenol could be the more appropriate under average conditions. However, silthiofam gave better control of take-all and larger yield responses, especially where the disease was more severe.

In most cases, fuberidazole + triadimenol did not give a yield benefit when sown in October, and the average benefit from silthiofam was smaller. However, increases in excess of 0.75 t/ha were obtained where take-all was a particular problem, and so silthiofam could still be cost-effective under such conditions.

Excluding normal adjustments for sowing date, seedbed conditions and soil type, seed rates do not need to be altered as a result of using silthiofam in addition to a standard seed treatment. The optimum seed rate was the same for all three seed treatments, regardless of sowing date. It was, however, sensitive to grain price at the later sowing date. There was no evidence that higher seed rates than normal are required to maximise the benefit from take-all seed treatments, and indeed this could be detrimental due to an increased incidence of take-all. A slight upward adjustment may sometimes be necessary with fuberidazole + triadimenol when sown in October, especially on heavy land, due to reduced establishment.

Finally, whether drilling in mid September or mid October, it is clear that even with a specific seed treatment only partial control of take-all can currently be achieved, so it is essential to maintain all other husbandry practices which are known to help minimise the effects of the disease.

The Effects of Sowing Date and Seed Treatment on Appropriate Nitrogen Fertiliser Management for Second Wheats, to Minimise the Impact of Take-all on Yield.

1. Introduction

Sound crop husbandry, together with careful planning of rotations and sowing dates, have formed a basis for the control of take-all (*Gaeumannomyces graminis* var. *tritici*) for many years. Nitrogen fertiliser management is a key element in the successful production of all cereals, but for a crop which is at risk from take-all this has even greater significance. This is because the damage caused by the disease to the root system, in particular the central stele, can drastically affect the uptake of nitrogen from the soil. The problem becomes worse as the season progresses, and the severity of take-all infection increases. Previous work by Arable Research Centres and others has demonstrated the importance of applying adequate early spring nitrogen, to help overcome the root damage caused by take-all. This has long formed part of the husbandry advice for second or subsequent wheat crops at risk from take-all (MAFF, 1986).

However, there are a number of other considerations for the effective use of nitrogen fertilisers on such crops. Huber *et al.* (1968) showed that fertilisation with ammonium nitrate could increase the severity of take-all on the roots, even if the proportion of whiteheads was decreased. By contrast, ammonium sulphate reduced the amount of infected tissue. Others have reported that ammonium nitrogen favours antagonistic micro-organisms such as *Pseudomonads* more than nitrate nitrogen, although high levels of ammonium can also encourage saprophytic survival of the take-all fungus. More recently, it has been suggested that splitting the fertiliser dose into more applications of smaller amounts better matches supply with the reduced capacity for uptake (Lucas *et al*., 1997).

The main objective of this research was to examine whether the use of a seed treatment offering control of take-all, in this case silthiofam (Latitude), might necessitate any alterations to current advice to apply an adequate nitrogen dose in early spring, or on the total amount of nitrogen fertiliser applied to the crop. With increasing evidence that too much early nitrogen is detrimental to early-sown first wheats, the implications of earlier drilling of second wheats treated with a take-all seed treatment also needed investigation, to develop appropriate nitrogen strategies for these crops. Determining the optimum nitrogen fertiliser rate for second wheats was not an objective. The increased early doses of nitrogen fertiliser would however provide an opportunity to make further observations of any effects on take-all development.

2. Materials and Methods

2.1 Overview

Replicated small plot trials were carried out at four contrasting locations in England during the 1997/1998, 1998/99 and 1999/2000 seasons. In this trials series (series two) the winter wheat variety Consort was drilled at a seed rate of 400 seeds/m^2 following wheat at two target sowing dates (10th September and 10th October). Two seed treatments were used, fludioxonil ('Beret Gold') and fludioxonil plus silthiofam ('Beret Gold' plus 'Latitude'). Six nitrogen fertiliser treatments were examined for both sowing dates and seed treatments. These were three total application rates (160, 200 and 240 kg N/ha), and two split timings (20% or 40% as a first dose at GS25-27 in early March, with the remainder applied at around GS31 in mid April). Other crop protection inputs were applied according to normal practice for each site. Plant, shoot and ear populations, root infection with take-all, and incidence of whiteheads were assessed in selected treatments. Grain yields were determined using a plot combine, and samples taken for physical analysis.

2.2 Site Details and Sowing Dates

The four locations, their soil types, and the sowing dates achieved in each season, are shown in Table 2.1. In general, trials were drilled within 1 week of their target date. The only significant departure from this was in the South in autumn 1999, when wet weather meant that both drilling dates were delayed until October.

Table 2.1 Site Details and Sowing Dates

Location	Soil Type	Actual Sowing Dates		
		1997/98	1998/99	1999/2000
North - Great Carlton (Lincolnshire)	heavy fine clay loam	22 September 8 October	18 September 12 October	18 September 6 October
South - Wye (Kent)	medium brickearth / silt loam	11 September 14 October	11 September 19 October	7 October 27 October
East - Kettering (Northamptonshire)	heavy chalky boulder clay	11 September 9 October	14 September 16 October	17 September 14 October
West - Cirencester (Gloucestershire)	light limestone brash	10 September 9 October	11 September 16 October	13 September 15 October

2.3 Seed Treatment Details

Application rates for the two seed treatments examined are shown in Table 2.2. A single batch of Consort seed was used for both treatments (and all four sites) each year.

Table 2.2 Seed Treatment Application Rates

Active Ingredient (s)	Product (s)	Application Rate
fludioxonil	Beret Gold	5 g ai / 100 kg seed
fludioxonil + silthiofam	Beret Gold + Latitude	5 + 25 g ai / 100 kg seed

2.4 Nitrogen Fertiliser Treatments

Three total application rates (160, 200 and 240 kg N/ha), and two split timings (20% or 40% as a first dose) were evaluated, as shown in Table 2.3. Wet conditions delayed some of the April applications in 1998 and 1999. The range of application dates achieved can be found in appendix C.

Table 2.3 Nitrogen Fertiliser Treatments

Treatment Number	Nitrogen Fertiliser Applied (kg N/ha) GS25-27 (early March)	GS30-31 (mid April)	Total Applied
N1	32	128	160
N2	64	96	160
N3	40	160	200
N4	80	120	200
N5	48	192	240
N6	96	144	240

2.5 Assessment Details

For nitrogen treatments N3 and N4 only, plant populations were determined at GS13 by counting 6 x 1.0m row lengths per plot (4 of which were in marked areas). Spring shoot counts were carried out on 4 x 1.0m rows per plot at the end of GS30 in the same marked areas. The number of shoots per plant was then able to be calculated. For all treatments, ear populations were determined pre-harvest by counting 6 x 1.0m rows per plot (4 in the marked areas), and the number of ears per plant then calculated for N3 and N4.

For nitrogen treatments N3 and N4 only, root infection with take-all was assessed at a minimum of two timings, GS31 and GS65. At each timing, 4 x 0.25m row lengths were dug at random from each plot, avoiding the outside rows. Roots were then washed after excess soil had been removed. Both the incidence (number of plants affected) and severity (percentage of root area affected) of take-all necrosis were recorded. A take-all severity index was then calculated (see appendix A). The incidence of whiteheads was scored as a percentage of the whole plot at GS77 for all treatments. Levels of other potential causal agents (eyespot and Fusarium species) were also noted. Fresh grain yields were determined using a plot combine, and these were adjusted for moisture content and plot size to give a yield in tonnes/ha at 15% moisture content. Specific weight (kg/hl) and thousand grain weight (g) were measured from each plot sample.

2.6 Trial Design and Statistical Analysis

Each year, trials were sown to a pre-determined layout. In 1997/1998 a randomised split plot design was used, with sowing date as the main plot and seed treatment x nitrogen as the sub-plot. In the second and third years, a randomised split-split plot design was used, with sowing date as the main plot, seed treatment as the sub-plot, and nitrogen as the sub-sub-plot. These were replicated four times. Analysis of variance was carried out on all data, with a cross-site comparison for key results each year, and an over-year analysis for grain yield.

3. Results

The results from the series two trials over three seasons are divided into three areas: 3.1 - Grain Yield, 3.2 - Crop Structure and Yield Components, and 3.3 - Take-all Severity and Whitehead Incidence.

3.1 Grain Yield

Grain yield data are presented in sub-sections 3.1.1 - 1997/1998 season, 3.1.2 - 1998/1999 season, 3.1.3 - 1999/2000 season, and 3.1.4 - over-year analysis. No yields were recorded at Great Carlton in 1997/1998, due to site variability, and therefore the mean figures in the over-year analysis have been adjusted.

3.1.1 1997/1998 Season

At Cirencester and Wye, 1998 gave the highest yields of the three years for both drilling dates. The average yield for the September sowing was 7.25 t/ha, compared to 8.05 t/ha for October (P <0.001). Averaged over the two drilling dates, fludioxonil + silthiofam gave a mean yield of 7.79 t/ha, compared to 7.51 t/ha for fludioxonil alone (P = 0.002). Fludioxonil + silthiofam gave a significant yield increase over fludioxonil alone when sown in September, but not in October (see Table 3.1). At Wye, fludioxonil + silthiofam sown in September gave a similar yield to fludioxonil alone sown in October.

Table 3.1 1997/1998 Grain Yield Responses to Sowing Date and Seed Treatment

Target Sow Date	Seed Treatment(s)	Grain Yield (t/ha)				
		G Carlton	Wye	Kettering	Cirencester	Site Mean
10 September	fludioxonil	-	7.85	6.87	6.31	7.01
	fludioxonil + silthiofam	-	8.52	7.29	6.67	7.49
10 October	fludioxonil	-	8.57	8.05	7.42	8.01
	fludioxonil + silthiofam	-	8.76	7.94	7.53	8.08
F prob.		-	0.035	0.053	0.366	0.010
sed. (d.f.)		-	0.472 (3.4)	0.551 (3.4)	0.185 (14.8)	0.093 (10.0)

Grain yield increased with both the total rate of nitrogen fertiliser, and with 40% rather than 20% applied early. Neither seed treatment nor sowing date had a significant effect on the response to nitrogen (Table 3.2):

Table 3.2 Effects of Sowing Date and Seed Treatment on Yield Response to Nitrogen Treatment (3 Site Mean)

Nitrogen Treatment	Grain Yield (t/ha)				
	September-sown		October-sown		Mean Yield
No rate, early	fludioxonil	+ silthiofam	fludioxonil	+ silthiofam	
N1 160, 20%	6.47	7.14	7.68	7.73	7.25
N2 160, 40%	6.70	7.23	7.98	7.79	7.42
N3 200, 20%	6.57	7.07	7.69	7.74	7.27
N4 200, 40%	7.44	7.72	8.49	8.16	7.95
N5 240, 20%	7.37	7.78	8.12	8.31	7.89
N6 240, 40%	7.51	8.02	8.12	8.73	8.10
F prob.	0.516				<0.001
sed. (d.f.)	0.229 (10)				0.114 (10)

3.1.2 1998/1999 Season

The average yield of the September sowing was only 6.09 t/ha, compared to 7.55 t/ha for October (P <0.001). Fludioxonil + silthiofam gave a mean yield of 7.20 t/ha, compared to 6.43 t/ha for fludioxonil (P <0.001). Yield increases were substantial with October sowing as well as September, except at Great Carlton (Table 3.3):

Table 3.3 1998/1999 Grain Yield Responses to Sowing Date and Seed Treatment

Target Sow Date	Seed Treatment(s)	Grain Yield (t/ha) G Carlton	Wye	Kettering	Cirencester	Site Mean
10 September	fludioxonil	7.77	5.72	6.05	3.09	5.66
	fludioxonil + silthiofam	8.49	7.21	6.43	3.98	6.53
10 October	fludioxonil	8.58	7.38	6.81	6.08	7.21
	fludioxonil + silthiofam	8.74	7.92	7.46	7.39	7.88
F prob. sed. (d.f.)		0.054 0.163 (6)	0.096 0.338 (6)	0.393 0.203 (6)	0.651 0.615 (6)	0.003 0.040 (15)

Significant yield responses were obtained by increasing the total rate of nitrogen fertiliser, and the proportion applied early. This occurred equally at both sowing dates, and with or without silthiofam seed treatment. (Table 3.4). The average difference between the highest and lowest yielding nitrogen treatments was around 15% at all locations except Kettering, where it was only 4.5% (Table 3.5).

Table 3.4 Effects of Sowing Date and Seed Treatment on Yield Response to Nitrogen Treatment (4 Site Mean)

Nitrogen Treatment No rate, early	Grain Yield (t/ha) September-sown fludioxonil	September-sown + silthiofam	October-sown fludioxonil	October-sown + silthiofam	Mean Yield
N1 160, 20%	5.35	6.22	6.91	7.52	6.50
N2 160, 40%	5.64	6.47	6.81	7.66	6.65
N3 200, 20%	5.34	6.45	7.15	7.80	6.69
N4 200, 40%	5.69	6.66	7.24	8.06	6.92
N5 240, 20%	5.74	6.41	7.44	7.88	6.87
N6 240, 40%	6.16	6.95	7.72	8.35	7.29
F prob. sed. (d.f.)	0.328 (sowing date x seed treatment x nitrogen treatment) 0.098 (15)				<0.001 0.049 (15)

Table 3.5 Effect of Location on Yield Response to Nitrogen Treatment

Nitrogen Treat. No rate, early	Grain Yield (t/ha) Great Carlton	Wye	Kettering	Cirencester
N1 160, 20%	7.86	6.67	6.56	4.92
N2 160, 40%	7.90	7.12	6.55	5.01
N3 200, 20%	8.34	6.86	6.68	4.87
N4 200, 40%	8.60	7.06	6.70	5.30
N5 240, 20%	8.66	7.02	6.80	4.99
N6 240, 40%	9.00	7.62	6.85	5.71
F prob. sed. (d.f.)	<0.001 0.117 (60)	0.001 0.209 (60)	0.005 0.089 (60)	<0.001 0.203 (60)

3.1.3 1999/2000 Season

Kettering and Great Carlton gave their highest yields at both sowing dates in 2000. Over the four sites, the average yield of the September sowing was 7.21 t/ha, compared to 8.07 t/ha for October (P <0.001). Fludioxonil + silthiofam gave a mean yield of 7.67 t/ha, compared to 7.61 t/ha for fludioxonil alone. The only site to give a significant yield benefit with silthiofam was Great Carlton, for the September sowing date (0.25 t/ha, P <0.001). Yield responses were obtained by increasing the total rate of nitrogen fertiliser, and in some cases the proportion applied early. This applied to both sowing dates and seed treatments (Table 3.6):

Table 3.6 Effects of Sowing Date and Seed Treatment on Yield Response to Nitrogen Treatment (Site Mean)

Nitrogen Treatment	Grain Yield (t/ha)				
	September-sown		October-sown		Mean Yield
No rate, early	fludioxonil	+ silthiofam	fludioxonil	+ silthiofam	
N1 160, 20%	6.89	6.90	7.92	7.81	7.38
N2 160, 40%	7.08	7.09	7.77	7.82	7.44
N3 200, 20%	7.19	7.27	8.07	8.12	7.65
N4 200, 40%	7.19	7.31	8.11	8.16	7.69
N5 240, 20%	7.24	7.44	8.18	8.23	7.77
N6 240, 40%	7.40	7.52	8.26	8.42	7.90
F prob.	0.455 (sowing date x seed treatment x nitrogen treatment)				<0.001
sed. (d.f.)	0.081 (15)				0.041 (15)

The responses varied in magnitude between the four locations. At Cirencester and Great Carlton, the mean differences between the highest and lowest yielding nitrogen treatment were large, at 10 and 13% respectively. At Kettering and Wye, the differences were small at only 3 and 5% (see Table 3.7). The site at Kettering had previously received applications of organic manure.

Table 3.7 Effect of Location on Yield Response to Nitrogen Treatment

Nitrogen Treat.	Grain Yield (t/ha)			
No rate, early	Great Carlton	Wye	Kettering	Cirencester
N1 160, 20%	8.24	7.31	8.77	5.20
N2 160, 40%	8.41	7.25	8.81	5.28
N3 200, 20%	8.76	7.53	8.84	5.48
N4 200, 40%	8.85	7.54	8.82	5.56
N5 240, 20%	9.12	7.61	8.95	5.42
N6 240, 40%	9.31	7.59	9.00	5.70
F prob.	<0.001	0.001	0.052	<0.001
sed. (d.f.)	0.089 (60)	0.071 (60)	0.083 (60)	0.101 (60)

3.1.4 Over-Year Analysis

Over the three seasons, the mean grain yield from September drilling was 7.04 t/ha compared to 8.00 t/ha from October, a penalty of 0.96 t/ha (P<0.001). The average yield with fludioxonil + silthiofam seed treatment was 7.70 t/ha, compared to 7.34 t/ha with fludioxonil alone, an increase of 0.36 t/ha (P <0.001). The benefit from the addition of silthiofam was 0.49 t/ha when sown in September, and 0.23 t/ha in October. Nitrogen treatment had a significant effect on yield over the three years, and neither seed treatment nor sowing date altered this (see Table 3.8). Overall, the highest yielding was 240 kg N/ha with 40% applied early, and this was 10.7% higher yielding than 160 kg N/ha with 20% applied early. The average yield for the 160 kg N/ha total nitrogen rate was 7.23 t/ha, compared to 7.52 t/ha for 200 kg N/ha (a 4% increase) and 7.82 t/ha for 240 kg N/ha (a further 4% increase). The average yield with 20% of the total nitrogen dose applied early was 7.40 t/ha, compared to 7.64 t/ha with 40% applied early (an increase of 3%).

Table 3.8 Effects of Seed Treatment on Yield Response to Nitrogen (4 Site Mean) - Three Year Average

Nitrogen Treatment No rate, early	Grain Yield (t/ha)				
	September-sown		October-sown		Mean Yield
	fludioxonil	+ silthiofam	fludioxonil	+ silthiofam	
N1 160, 20%	6.40	6.93	7.59	7.75	7.17
N2 160, 40%	6.65	7.08	7.62	7.82	7.29
N3 200, 20%	6.55	7.11	7.77	7.99	7.35
N4 200, 40%	6.97	7.43	8.08	8.24	7.68
N5 240, 20%	6.98	7.45	8.06	8.27	7.69
N6 240, 40%	7.22	7.72	8.19	8.62	7.94
F prob.	0.681 (sowing date x seed treatment x nitrogen treatment)				<0.001
sed. (d.f.)	0.094 (105)				0.047 (105)

Over the three years, the differences between the highest and lowest yielding nitrogen treatments were 14% at Great Carlton, 12% at Cirencester and Wye, and 4% at Kettering (Table 3.9). Great Carlton gave an 11% yield increase with total nitrogen rate, but only a 2% increase with a higher proportion applied early. Wye and Cirencester gave an 8% yield increase with total nitrogen rate, and a 4% increase with a higher proportion early. Kettering gave a 3% increase with total nitrogen rate, and a 1.5% increase with more applied early.

Table 3.9 Effect of Location on Yield Response to Nitrogen Treatment - Three Year Average

Nitrogen Treat.	Grain Yield (t/ha)			
No rate, early	Great Carlton	Wye	Kettering	Cirencester
N1 160, 20%	8.05	7.25	7.57	5.57
N2 160, 40%	8.16	7.49	7.61	5.67
N3 200, 20%	8.55	7.48	7.54	5.66
N4 200, 40%	8.72	7.81	7.78	6.03
N5 240, 20%	8.89	7.75	7.80	5.93
N6 240, 40%	9.16	8.12	7.88	6.25
F prob.	<0.001	<0.001	0.003	<0.001
sed. (d.f.)	0.034 (5)	0.061 (10)	0.071 (10)	0.079 (10)

3.2 Crop Structure and Yield Components

Results from the shoot and ear population counts, and thousand grain weight measurements, for each of the seasons are presented in sub-sections 3.2.1 - 3.2.3, with a summary in 3.2.4.

3.2.1 1997/1998 Season

At Great Carlton, Wye and Kettering, applying 40% of the total nitrogen early instead of 20% increased shoot populations with both seed treatments. There was no significant interaction with seed treatment except at Cirencester, where fludioxonil showed an increase but fludioxonil + silthiofam did not (Table 3.10). This appears to have resulted from variation in initial plant populations, and there were only small differences in the number of shoots per plant. Overall, seed treatment had little effect on shoot populations at any of the sites.

Table 3.10 Effect of Seed Treatment and Early Nitrogen Dose on Shoot Populations

Seed Treatment	Nitrogen Treat. No rate, early	Shoots per m^2 at GS30			
		Great Carlton	Wye	Kettering	Cirencester
fludioxonil	N3 200, 20%	310	800	950	453
	N4 200, 40%	314	839	1033	506
fludioxonil + silthiofam	N3 200, 20%	282	815	963	544
	N4 200, 40%	318	846	1112	453
F prob. (seed treat. x nitrogen)		0.277	0.887	0.337	0.029
sed. (d.f.)		20 (18)	35 (18)	48 (18)	43 (18)

Both ear population and thousand grain weight showed significant increases with fludioxonil + silthiofam seed treatment compared to fludioxonil alone. Average ear population increased from 350 ears/m^2 to 370 ears/m^2 (P <0.001), and thousand grain weight from 45.4g to 46.2g (P = 0.004). Similar responses were seen with nitrogen treatment (Table 3.11), although there appeared to be no overall advantage from increasing the total rate above 200 kg N/ha. Seed treatment had no effect on the responses to nitrogen treatment, and their combined effect was to increase average ear population from 336 to 383 ears/m^2 (14%), and thousand grain weight from 44.7g to 46.9g (5%). The greatest benefits occurred at Wye.

Table 3.11 Effect of Nitrogen Treatment on Ear Population and Thousand Grain Weight

Nitrogen Treat. No rate, early	Wye		Four Site Mean	
	Ears per m^2	TGW (g)	Ears per m^2	TGW (g)
N1 160, 20%	379	45.4	350	45.7
N2 160, 40%	398	45.7	350	45.0
N3 200, 20%	383	45.6	360	45.1
N4 200, 40%	431	46.8	375	46.4
N5 240, 20%	402	46.7	355	46.4
N6 240, 40%	426	47.8	371	46.3
F prob.	<0.001	<0.001	0.008	0.006
sed. (d.f.)	11.4 (66)	0.51 (66)	7.0 (15)	0.41 (15)

3.2.2 1998/1999 Season

At Great Carlton, applying 40% of the total nitrogen early instead of 20% increased shoot populations with both seed treatments. Fludioxonil + silthiofam also showed a clear response at Wye and Kettering, but fludioxonil alone did not. This interaction was significant at Wye (see Table 3.12), and there was a similar interaction for the number of shoots per plant (P = 0.006). Neither seed treatment nor early nitrogen dose had a significant effect on shoot populations at Cirencester.

Table 3.12 Effect of Seed Treatment and Early Nitrogen Dose on Shoot Populations

Seed Treatment	Nitrogen Treat. No rate, early	Shoots per m^2 at GS30 Great Carlton	Wye	Kettering	Cirencester
fludioxonil	N3 200, 20%	308	810	938	456
	N4 200, 40%	331	810	944	454
fludioxonil + silthiofam	N3 200, 20%	321	697	975	469
	N4 200, 40%	338	895	1024	446
F prob. (seed treat. x nitrogen)		0.810	0.003	0.517	0.756
sed. (d.f.)		14 (18)	54 (8)	42 (17)	40 (18)

The average ear population increased from 352 ears/m^2 with fludioxonil to 374 ears/m^2 with fludioxonil + silthiofam, and thousand grain weight increased from 41.6g to 43.6g. Both were significant (P <0.001). Nitrogen treatment also had a significant effect on ear population and thousand grain weight (Table 3.13). There were increases with both total nitrogen rate and a higher proportion applied early. The effect on ear population was greatest at Wye, whereas thousand grain weight benefited most at Great Carlton. Responses to nitrogen treatment were obtained with both seed treatments, and their combined effect was to increase average ear population from 342 to 392 ears/m^2 (15%), and thousand grain weight from 41.1g to 45.2g (10%).

Table 3.13 Effect of Nitrogen Treatment on Ear Population and Thousand Grain Weight

Nitrogen Treat. No rate, early	Wye Ears per m^2	Great Carlton TGW (g)	Four Site Mean Ears per m^2	Four Site Mean TGW (g)
N1 160, 20%	411	47.4	348	42.1
N2 160, 40%	446	47.8	365	42.3
N3 200, 20%	423	47.6	354	42.0
N4 200, 40%	436	49.1	367	42.4
N5 240, 20%	432	49.1	364	42.8
N6 240, 40%	460	49.7	380	43.7
F prob.	<0.001	0.003	<0.001	0.005
sed. (d.f.)	10.2 (60)	0.66 (60)	4.2 (15)	0.38 (15)

3.2.3 1999/2000 Season

At Great Carlton and Wye, applying 40% of the nitrogen early increased both shoot populations and the number of shoots per plant, but this was only significant at Wye (P = 0.01 and P <0.001). The two seed treatments responded similarly. At Kettering, only fludioxonil alone showed an increase, but this interaction was not significant (Table 3.14). Seed treatment itself had no consistent effect .

Table 3.14 Effect of Seed Treatment and Early Nitrogen Dose on Shoot Populations

Seed	Nitrogen Treat.	Shoots per m^2 at GS30

Treatment	No rate, early	Great Carlton	Wye	Kettering	Cirencester
fludioxonil	N3 200, 20%	623	870	941	400
	N4 200, 40%	634	932	982	414
fludioxonil +	N3 200, 20%	618	843	972	422
silthiofam	N4 200, 40%	651	879	960	422
F prob. (seed treat. x nitrogen) sed. (d.f.)		0.400 15 (18)	0.970 34 (10)	0.313 41 (13)	0.756 26 (18)

Seed treatment had a small but significant effect on thousand grain weight, which increased from 45.3g with fludioxonil to 45.7g with fludioxonil + silthiofam (P = 0.018). There was a small increase in ear population between the lowest and highest nitrogen treatments, but no consistent increase in thousand grain weight (see Table 3.15). The effect on ear population was greatest at Great Carlton, and only Wye showed significant differences in thousand grain weight. The combined effect of nitrogen and seed treatment was to increase the average ear population from 433 to 456 ears/m^2 (5%), and thousand grain weight from 45.4g to 46.3g (2%).

Table 3.15 Effect of Nitrogen Treatment on Ear Population and Thousand Grain Weight

Nitrogen Treat. No rate, early	Great Carlton Ears per m^2	Wye TGW (g)	Four Site Mean Ears per m^2	Four Site Mean TGW (g)
N1 160, 20%	340	45.5	431	45.4
N2 160, 40%	359	46.2	452	46.0
N3 200, 20%	362	44.7	449	45.2
N4 200, 40%	355	45.0	447	45.0
N5 240, 20%	360	44.9	450	45.4
N6 240, 40%	384	46.5	454	45.9
F prob. sed. (d.f.)	<0.001 3.5 (60)	0.012 0.59 (60)	0.002 4.5 (15)	0.026 0.28 (15)

3.2.4 Summary

In most of the trials, increasing the proportion of nitrogen applied early, from 20% to 40%, resulted in an increase in shoot populations (and number of shoots per plant). Generally, both seed treatments gave similar responses, and where interactions did occur, these were usually either not significant or could be related to differences in initial plant populations. In 1998 and1999, both thousand grain weights and ear populations increased as a result of changing seed treatment, from fludioxonil to fludioxonil + silthiofam. They also responded to increasing the total nitrogen rate and/or applying more early. The greatest improvements were obtained by combining seed treatment and nitrogen changes. In 2000 responses were small, but as before Wye and Great Carlton appeared to benefit the most.

3.3 Take-all Severity and Whitehead Incidence

Results from the root take-all assessments at GS31 in April and GS65 in June, and the late season assessment of whitehead incidence, are presented for each year in sub-sections 3.3.1 - 3.3.3, with a summary in 3.3.4. Root take-all assessments were carried out only on nitrogen treatments N3 (200 kg N/ha, 20% early) and N4 (200 kg N/ha, 40% early).

3.3.1 1997/1998 Season

The proportion of plants with take-all necrosis on their roots averaged 19% at GS31 and 47% at GS65. Levels were highest at Wye and lowest at Kettering. At GS31, 25% of plants were affected in the September drilled but only 14% in the October. Severity also was lower in the later sowing, with an index of 17.1 for September compared to 14.8 for October at GS65. Fludioxonil + silthiofam had less take-all than fludioxonil alone at all four sites, although differences were not significant at Great Carlton or Cirencester. The average severity indices at GS65 were 19.7 for fludioxonil compared to 12.2 for fludioxonil + silthiofam. At Great Carlton and Wye, take-all severity was lower with 40% of the nitrogen early than with 20%, at both GS31 and GS65. At Cirencester, there were no differences. At Kettering, take-all severity was higher at GS31 but lower at GS65 with 40% early nitrogen (Table 3.16). However, none of these differences were significant.

Table 3.16 Effects of Nitrogen and Seed Treatment on Take-all Severity (Kettering)

Nitrogen treat.	**Severity Index at GS31**			**Severity Index at GS65**		
No rate, early	fludioxonil	+ silthiofam	Mean	fludioxonil	+ silthiofam	Mean
N3 200, 20%	1.75	0.91	1.33	7.74	3.16	5.45
N4 200, 40%	2.13	1.41	1.77	4.90	3.21	4.06
Mean	1.94	1.16		6.32	3.19	
F prob. sed. (d.f.)	0.031 0.335 (18)		0.198 0.335 (18)	0.009 1.06 (18)		0.206 1.06 (18)

3.3.2 1998/1999 Season

The proportion of plants with take-all necrosis on their roots averaged 33% at GS31 and 68% at GS65. Levels were highest at Cirencester and lowest at Great Carlton. At GS31, there was a significant difference between sowing dates ($P < 0.001$), with 50% affected in the September drilled but only 17% in the October. By GS65, the difference was smaller. Take-all severity was significantly lower for the later sowing at both assessment stages, with an index of 28.7 for September compared to 14.0 for October at GS65. Seed treatment also had an effect on take-all levels. Fludioxonil + silthiofam had a lower recorded incidence and severity (see Table 3.17) than fludioxonil alone. At GS31, the take-all index was significantly higher with 40% early nitrogen than with 20% early. At GS65, the index was lower with 40% early (this was not significant).

Table 3.17 Effects of Nitrogen and Seed Treatment on Take-all Severity (4 Site Mean)

Nitrogen treat.	Severity Index at GS31			Severity Index at GS65		
No rate, early	fludioxonil	+ silthiofam	Mean	fludioxonil	+ silthiofam	Mean
N3 200, 20%	8.24	3.08	5.66	29.7	18.2	24.0
N4 200, 40%	9.45	4.38	6.92	24.8	12.6	18.7
Mean	8.85	3.73		27.3	15.4	
F prob. sed. (d.f.)	<0.001 0.158 (3)		0.004 0.158 (3)	0.076 4.5 (3)		0.322 4.5 (3)

At Wye and Kettering, the incidence of whiteheads decreased with increasing nitrogen rate and with a higher proportion applied early (Table 3.18). There were no obvious differences at the other two sites.

Table 3.18 Effect of Location and Nitrogen Treatment on Whitehead Incidence

Nitrogen Treat.	% Whiteheads	
No rate, early	Wye	Kettering
N1 160, 20%	38	52
N2 160, 40%	32	51
N3 200, 20%	35	48
N4 200, 40%	31	46
N5 240, 20%	34	47
N6 240, 40%	28	44
F prob.	0.075	<0.001
sed. (d.f.)	3.4 (60)	1.7 (60)

3.3.3 1999/2000 Season

The proportion of plants with take-all necrosis on their roots averaged 31% at GS31 and 55% at GS65. Levels were highest at Cirencester and lowest at Kettering. At GS31, 43% were affected in the September sown but only 18% in the October ($P = 0.001$). Take-all severity was also lower for the later sowing at both assessment stages, with an index of 14.0 for September compared to 7.0 for October at GS65 ($P = 0.001$). Take-all levels were lower with fludioxonil + silthiofam than with fludioxonil at both GS31 and GS65, although differences were only bordering on significant. There were no differences between nitrogen treatments (see Table 3.19):

Table 3.19 Effects of Nitrogen and Seed Treatment on Take-all Severity (4 Site Mean)

Nitrogen treat.	Severity Index at GS31			Severity Index at GS65		
No rate, early	fludioxonil	+ silthiofam	Mean	fludioxonil	+ silthiofam	Mean
N3 200, 20%	3.72	3.32	3.52	13.2	8.9	11.05
N4 200, 40%	4.00	2.86	3.43	12.8	9.1	10.95
Mean	3.86	3.09		13.0	9.0	
F prob. sed. (d.f.)	0.074 0.287 (3)		0.776 0.287 (3)	0.055 1.19 (3)		0.988 1.19 (3)

At Great Carlton, the incidence of whiteheads was significantly lower with fludioxonil + silthiofam than with fludioxonil alone. There was also a reduction with increasing nitrogen rate, but no benefit from a higher proportion applied early (Table 3.20). There were no differences between nitrogen treatments at the other sites.

Table 3.20 Effect of Nitrogen and Seed Treatment on Whitehead Incidence at Great Carlton

Nitrogen Treat.	% Whiteheads		
No rate, early	fludioxonil	+ silthiofam	Mean
N1 160, 20%	32	14	23
N2 160, 40%	34	22	28
N3 200, 20%	23	9	16
N4 200, 40%	24	6	15
N5 240, 20%	14	3	8
N6 240, 40%	16	6	11
Mean	24	10	
F prob. sed. (d.f.)	0.020 4.4 (6)		<0.001 3.5 (60)

3.3.4 Summary

Take-all incidence was highest in 1999 and lowest in 1998, but severity was lowest in 2000. Both incidence and severity were higher in the September drilled than the October, especially at GS31. Levels of take-all were consistently lower with fludioxonil + silthiofam treatment than with fludioxonil alone. In 1998 and 1999, there was a tendency for take-all severity to be lower at GS65 where 40% of the nitrogen had been applied early rather than 20%. However, at GS31, severity was generally either increased or unaffected as a result of applying the higher early nitrogen dose. Nitrogen treatment had no effect at either timing in 2000.

4. Discussion

4.1 Grain Yield

The average yield penalty incurred as a result of advancing drilling from October to September was 1.09 t/ha, using the standard seed treatment (fludioxonil). Adding silthiofam to fludioxonil reduced this slightly, but there was still a decrease of 0.83 t/ha with earlier drilling. September-sown fludioxonil + silthiofam gave an average yield of 7.29 t/ha, compared to 7.88 t/ha for fludioxonil alone sown in October. Therefore, there was a yield reduction of more than half a tonne per hectare even where silthiofam seed treatment was used to offset the penalty due to earlier drilling. With an average yield increase of 0.49 t/ha, and a range of -0.15 to +1.49 t/ha, it is clear that the addition of silthiofam was generally beneficial when sowing in September. The range of yield increases from using silthiofam in October was similar, at -0.11 to +1.31 t/ha. But with an average increase of only 0.23 t/ha, the number of situations where a benefit was obtained was less.

Grain yield was clearly responding to nitrogen treatment, although more so in the first two years than in 2000. The application rates evaluated were based on a control treatment (200 kg N/ha), plus higher (240 kg N/ha) and lower (160 kg N/ha) rates to determine the implications of using the take-all seed treatment and/or earlier sowing. Trials by Arable Research Centres had indicated that 200 kg N/ha was close to optimum for winter wheat crops on the soil types included in these trials, but that in the presence of take-all higher doses may be appropriate. The sixth edition of the MAFF Fertiliser Recommendations Booklet RB209 (MAFF, 1994) also indicated that, for an expected yield of 7-9 t/ha and an N index 0 situation, the appropriate rate for three of the soil types was 200 kg N/ha. At Cirencester, 225 kg N/ha would have been appropriate for the same yield, but with successive wheat crops barely reaching 7 t/ha on this soil 175 kg N/ha was indicated. These recommendations have now been superseded by the seventh edition of Booklet RB209 (MAFF, 2000), and expected yield is no longer considered to be a key factor. Nevertheless nitrogen fertiliser rates have often been reduced for second and subsequent wheats on the assumption that their yield may be restricted by take-all.

Application of an early dose of nitrogen fertiliser during tillering in late February or early March was known to be important for crops at risk from take-all. Indeed, ARC trials had shown that not only was early nitrogen necessary, but where take-all was severe a larger amount than the standard 40 kg N/ha could be beneficial where the main dose was not applied until April. As these crops have usually been sown later, they should not be at such high risk from the problems associated with early applications to earlier sown, well-tillered first wheats. What was unclear was whether the same strategy would be appropriate for an early sown second wheat, at high risk from take-all, and whether this would be affected by the use of a take-all seed treatment. Inevitably, yield responses in nitrogen timing trials also reflect seasonal factors, which can affect both the dates when treatments are applied and the ability of the crop to take up nitrogen. These trials included a range of timings within the February/March and April treatment windows, but in all cases wet weather ensured moist soil conditions after application.

Using nitrogen treatment N3 (200 kg N/ha, 20% early) as the control, and treatment N6 (240 kg N/ha, 40% early) as the comparison, the average yield increase was 0.59 t/ha. Half of this could be attributed to the extra 40 kg N/ha applied, and half due to the larger first dose. The individual responses for each of the sowing date and seed treatment combinations were:

September-sown, fludioxonil	+0.67 t/ha
September-sown, fludioxonil + silthiofam	+0.61 t/ha
October-sown, fludioxonil	+0.42 t/ha
October-sown, fludioxonil + silthiofam	+0.63 t/ha

The results clearly indicate that use of silthiofam seed treatment, whether drilled in September or October, does not affect the importance of applying a sufficiently high rate of nitrogen, or a large enough first dose.

Other factors did affect the magnitude of the response to nitrogen treatment, in particular location and the severity of take-all. Kettering gave the smallest yield benefits over the three years. This may have been due to sites at this location receiving applications of organic manure in previous years. At Wye, large yield increases were obtained in 1998 and 1999 when take-all severity was relatively high, but in 2000 there was very little response. Treatment application dates also differed, but appear to have been of less consequence (Table 4.1):

Table 4.1 Seasonal Variation in Take-all Severity and Yield Response to Nitrogen Treatment at Wye

Year	Yield Increase (N6 vs N3)	Take-all Severity Index	N Application Dates
1998	1.12 t/ha (13%)	53	24 Feb and 22 April
1999	0.76 t/ha (11%)	32	25 Feb and 8 April
2000	0.06 t/ha (1%)	12	23 Feb and 10 April

4.2 Economic Analysis

As shown in the previous section, the average yield increase from the use of silthiofam seed treatment in September was 0.49 t/ha, which would have been worth £29-37/ha for a grain price range of £60-75 per tonne. With fludioxonil seed treatment, the benefit from increasing the total nitrogen rate from 200 to 240 kg/ha, and applying 40% rather than 20% early, was 0.67 t/ha, worth £40-50/ha. Combining silthiofam seed treatment with the additional nitrogen, the mean yield increase was 1.17 t/ha, worth £70-88/ha. Subtracting the cost of the extra nitrogen fertiliser (£14/ha at £0.35 per kg), would leave £56-74/ha before the cost of the extra seed treatment. The latter will depend on the cost per tonne of the treated seed, and the seed rate used.

When sown in October, the average yield increase with silthiofam was 0.23 t/ha, worth £14-17/ha (but note that this average includes a wide range of values). With fludioxonil seed treatment alone, the equivalent response to nitrogen treatment was 0.42 t/ha, worth £25-32/ha. However, combining the two gave a mean yield increase of 0.85 t/ha, worth £51-64/ha. Again, subtracting £14/ha for the extra nitrogen fertiliser would leave £37-44/ha before the cost of the additional seed treatment.

Clearly, the use of silthiofam would not have been justified as often with October sowing as with September. However, when used alongside an appropriate nitrogen strategy, the net result would have been an economic gain in a number of situations. Despite the larger benefits with earlier sowing, it is important to remember that in most cases September drilling would still have led to an economic loss.

4.3 Crop Structure, Yield Components and the Severity of Take-all

Examination of the crop structure and yield component results provides some explanation for the yield effects observed with nitrogen treatment. Increases in shoot populations (due to a greater number of shoots per plant) were obtained in most of the trials as a result of applying a larger first dose of nitrogen. In 1998 and 1999, ear populations also benefited from an increased nitrogen dose (either at the first timing or in total). Although the use of silthiofam seed treatment did not have a consistent effect on shoot populations, it did give an increase in ear populations in 1998 and 1999. Averaged over three years, the combined effect of adding silthiofam, and changing the nitrogen treatment from 200 kg N/ha with 20% early to 240 kg N/ha with 40% early, was to increase the mean ear population from 383 ears/m^2 to 410 ears/m^2 (7%). Similarly, thousand grain weight increased with both nitrogen treatment and silthiofam seed treatment, particularly in 1998 and 1999. The combined effect was an increase in the mean weight from 43.8g to 46.1g (5%). There may also have been an effect on the number of grains per ear, but this was not measured.

Take-all was present in all of the trials, even though the sites were chosen to be representative of second wheat fields, rather than soils with a history of take-all problems. This was partly due to weather conditions during the autumn and spring which favoured infection with the disease in all three years. 2000 was slightly different to the first two years, in that although the incidence of take-all was high initially, subsequent development was restricted and severity on individual plants tended to be low. Sowing date had the greatest effect over the three years, typically reducing take-all incidence and severity by half. Silthiofam seed treatment was also effective, reducing the disease severity by 30-50% at GS65.

Previous research had shown the relationship between take-all and nitrogen use to be complex. Although it was not a specific objective of the project to examine this, some differences between nitrogen treatments were observed in the first two years, but these were generally not significant. At GS31, both higher and lower take-all severity were recorded as a result of applying a larger first dose of ammonium nitrate, although in most cases it was higher. However, at GS65, severity tended to be lower where a larger first nitrogen dose had been applied. These differences were small compared to other factors, and are unlikely to have influenced yields.

5. Conclusions and Implications

Sowing a second wheat in mid September rather than mid October is likely to increase take-all and reduce yield. In this trials series, using the standard seed treatment fludioxonil alone, the average penalty was 1.0 t/ha. The addition of silthiofam can be expected to give partial control of the disease, here reducing late season severity by an average of 40%, and resulting in typical yield increases of 0.49 t/ha when sown in September or

0.23 t/ha in October. However, as occurred in these trials, increases in excess of 1.25 t/ha are possible at both sowing dates where take-all pressure is high.

Adopting an appropriate nitrogen fertiliser strategy is vital for second wheat crops at risk from take-all. This includes applying a sufficiently high total rate, and a large enough first dose. In these trials, applying an extra 40kg N/ha above the site standard, and 40% (rather than 20%) of the total dose at the first timing in late February or early March, improved yield by an average of 0.59 t/ha. It should be noted that the nitrogen treatments evaluated here were not intended to identify the optimum nitrogen rate for second wheats. This must still take into account key factors such as soil type, potential soil nitrogen supply and intended market for the crop (feed or breadmaking). It would also be inappropriate to conclude that the highest early dose of nitrogen used here (40% of 240 kg N/ha = 96 kg N/ha) should routinely be applied to second wheats. Increased lodging risk and higher foliar disease pressure could otherwise occur, and spray programmes would need to be adjusted. However, the results clearly indicate that where there is a take-all risk, a modest increase above the 40 kg N/ha typically applied during tillering could be beneficial where the main dose is not applied until April.

Sowing in September rather than October, and/or the use of silthiofam seed treatment, does not reduce the yield benefit obtained by altering the nitrogen fertiliser strategy. Equally, delaying drilling until October should still be the objective, even if seed treatment and nitrogen management are changed. Where September sowing is unavoidable, the impact of take-all on yield can be minimised by using a seed treatment accompanied by adequate early nitrogen fertiliser, and this has reduced potential yield losses by more than 1 t/ha. Where the early season take-all incidence is low, on medium or heavy soils, equal or higher yields can be achieved compared to a standard seed treatment sown in October. This is unlikely to be the case on lighter soils or where early season take-all levels are high. Regardless of the seed treatment and nitrogen strategy used, all other appropriate husbandry measures should still be maintained.

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Appendices

Appendix A

Formulae for Calculation of Take-all Incidence and Severity Index

The severity of root necrosis on each plant was recorded by category as follows

Category	% Root area affected
0	0
1	1-10
2	11-30
3	31-60
4	61-100

Incidence of Take-all was calculated as:

$$\frac{\text{Number of plants with Take-all}}{\text{Number of plants assessed}} \times 100\ \%$$

Take-all **Severity Index** was calculated as:

$$\frac{(0 \times a) + (10 \times b) + (30 \times c) + (60 \times d) + (100 \times e)}{\text{Total number of plants}}$$

where a, b, c, d and e are the number of plants in categories 0, 1, 2, 3 and 4 respectively

Appendix B

Dates and Growth Stages of Take-all and Whitehead Assessments

Assessment Number	Assessment Type	Assessment Timing	Assessment Dates
1 (optional)	root take-all	GS25	late Feb - early Mar
2 (compulsory)	root take-all	GS31	mid-late April
3 (compulsory)	root take-all	GS65	mid-late June
4 (optional)	root take-all	GS77	early-mid July
5 (compulsory)	whiteheads	GS77	early-mid July

Appendix C

Dates and Growth Stages of Nitrogen Fertiliser Applications

Experimental Year	Application Dates and Growth Stages	
	Target GS25-27 (early March)	Target GS30-31 (mid April)
1997/1998	25 February - 4 March GS23 - GS27	17 April - 30 April GS31 - GS31/32
1998/1999	24 February - 10 March GS23 - GS26	8 April - 29 April GS30/31 - GS31/32
1999/2000	23 February - 13 March GS24 - GS27	7 April - 14 April GS30/31 - GS31

Appendix D

Table of Margins over Cost of Treated Seed

Sowing Date	Seed Treatment	Seed rate seeds/m2	Yield (t/ha)	Output Value (£/ha) grain £60/t	grain £75/t	Seed cost (£/ha)	MOC treat seed (£/ha) grain £60/t	grain £75/t
Septem	fludioxonil	200	7.32	439.20	549.00	22.50	416.70	526.50
		300	7.39	443.40	554.25	33.75	409.65	520.50
		400	7.27	436.20	545.25	45.00	391.20	500.25
Septem	fludioxonil plus silthiofam	200	7.74	464.40	580.50	36.00	428.40	544.50
		300	7.80	468.00	585.00	54.00	414.00	531.00
		400	7.75	465.00	581.25	72.00	393.00	509.25
Septem	fuberidazole + triadimenol	200	7.71	462.60	578.25	27.00	435.60	551.25
		300	7.78	466.80	583.50	40.50	426.30	543.00
		400	7.58	454.80	568.50	54.00	400.80	514.50
Octob	fludioxonil	200	8.01	480.60	600.75	22.50	458.10	578.25
		300	8.22	493.20	616.50	33.75	459.45	582.75
		400	8.14	488.40	610.50	45.00	443.40	565.50
Octob	fludioxonil plus silthiofam	200	8.12	487.20	609.00	36.00	451.20	573.00
		300	8.41	504.60	630.75	54.00	450.60	576.75
		400	8.36	501.60	627.00	72.00	429.60	555.00
Octob	fuberidazole + triadimenol	200	7.88	472.80	591.00	27.00	445.80	564.00
		300	8.14	488.40	610.50	40.50	447.90	570.00
		400	8.23	493.80	617.25	54.00	439.80	563.25

Based on untreated seed at £180/t, fludioxonil seed treatment at £45/t, silthiofam at £135/t, fuberidazole + triadimenol at £90/t, thousand grain weight of 50g, grain prices of £60/t and £75/t

ANNEX

Abstract

In a 3-year HGCA-funded study between 1998 and 2000, it was shown that, even when seed treatments such as silthiofam and fuberidazole + triadimenol are used that can reduce the impact of take-all, it is still important to delay the sowing of second wheats from September until October, and to employ other crop husbandry measures that can help to alleviate the effects of the disease. Both seed treatment and sowing date can have implications for selecting an appropriate seed rate, and the project therefore investigated the effects of seed treatment on response to seed rate between 200 and 400 seeds/m^2, using fludioxonil as the control.

In the 2001 season, the seed rate range was extended down to 100 seeds/m^2, and a fourth seed treatment, fluquinconazole + prochloraz, was added. Three replicated trials were conducted at contrasting locations, with a target sowing date of late September. Plots were assessed for crop structure and yield components, take-all incidence and severity, and grain yield. Results were compared with those obtained in the 1998-2000 seasons.

Take-all was present at all three sites, but seed treatment differences were only recorded at two. Take-all severity in April was lower for fludioxonil + silthiofam and fluquinconazole + prochloraz than for fludioxonil alone. At one location, a higher incidence and severity of take-all were recorded at seed rates of 300 or 400 seeds/m^2 than at 100 or 200 seeds/m^2 with treatments that did not give control of the disease. Yield differences between seed treatments varied between sites, but fludioxonil + silthiofam was the highest ranking overall. A seed rate of 100 seeds/m^2 was below optimum regardless of treatment, but there was evidence of an interaction between seed treatment and rate at one location. The other treatments had a greater yield advantage over fludioxonil alone at the two higher seed rates than at the lower rates. However, the optimum seed rates (200-300 seeds/m^2) were the same for all seed treatments except fuberidazole + triadimenol (200 seeds/m^2).

Comparison of the 2001 results with equivalent trials in 1998-2000 showed similar seed rate responses for both fludioxonil alone and fludioxonil + silthiofam, although the yield benefit from silthiofam was above the previous average. The response for fuberidazole + triadimenol was different to previously. Increases in take-all incidence at higher seed rates had also been observed in some trials during the other three years.

The results suggest that, like silthiofam, a seed treatment based on fluquinconazole can give partial control of take-all. However, seed rate is also an important factor in managing second wheats at risk from take-all. Use of a non take-all seed treatment at a higher seed rate may cost less than a take-all treatment at a lower seed rate, but this could further depress yield. As later drilling is a key measure to reduce take-all impact, seed rates should however be adjusted to take into account sowing date, soil type and seedbed conditions.

Summary

Introduction

In a 3-year HGCA-funded study that preceded this investigation (HGCA Project Report No. 255) it was shown that, even when seed treatments are used that can reduce take-all, it is still important to delaying sowing from September until October. However, with the area of wheat being sown on many farms getting larger, an earlier start to second wheat drilling has become necessary. Both seed treatment and sowing date can have significant implications for selecting an appropriate seed rate. The study therefore examined the effects of seed treatment on response to seed rate, and the resulting take-all impact on grain yield. For seed rates ranging from 200 to 400 seeds/m^2, choice of seed treatment between fludioxonil (Beret Gold), fludioxonil + silthiofam (Beret Gold + Latitude), and fuberidazole + triadimenol (Baytan) did not alter the optimum seed rate for either September or October drilling. However, in some trials take-all incidence was greater at the highest seed rate.

The main objectives of this additional investigation were to extend the range of seed rates evaluated down to 100 seeds/m^2, allowing further evaluation of the cost/benefit relationship for silthiofam treatment, and to include fluquinconazole + prochloraz (Jockey) for comparison over the same range of seed rates.

Methods

Replicated trials were established to compare four seed treatments at four seed rates on a single winter wheat variety (cv. Consort). These were conducted on three second wheat sites at locations with contrasting soils, which were Great Carlton in Lincolnshire (heavy fine clay loam), Andover in Hampshire (light chalkland soil) and Cirencester in Gloucestershire (light limestone brash clay). The target sowing date was late September, but wet weather prevented Andover from being sown until early November. The seed treatments examined are shown in Table 1. The seed rates evaluated were 100, 200, 300 and 400 seeds/m^2.

Table 1 Seed Treatment Application Rates

Active Ingredient (s)	Product (s)	Application Rate
fuberidazole + triadimenol	Baytan Flowable	4.5 + 37.5 g ai / 100 kg seed
fludioxonil	Beret Gold	5 g ai / 100 kg seed
fludioxonil + silthiofam	Beret Gold + Latitude	5 + 25 g ai / 100 kg seed
fluquinconazole + prochloraz	Jockey	75 + 14 g ai / 100 kg seed

A randomised split plot trial design was used, with three yield and three sampling replicates. Assessments carried out included autumn plant populations, spring shoot populations and ear counts, in marked quadrats. Root infection with take-all was assessed in April (at GS31) and June (at GS65). Both the incidence (number of plants affected) and severity (percentage of root area affected) of take-all necrosis were recorded, and converted to a severity index. All trials were taken to yield, and thousand grain weights were measured.

2001 Results

Effects of Seed Treatment

Plant populations varied between sites, but there were no differences between seed treatments apart from at Cirencester, where establishment averaged only 60% for fuberidazole + triadimenol and fluquinconazole + prochloraz, compared to 70% for fludioxonil. Seed treatment also had little effect on shoot or ear populations, although highest values were always recorded with fluquinconazole + prochloraz or fludioxonil + silthiofam. At Cirencester, comparison of the yield components and grain yield shows a clear relationship (Table 2):

Table 2 Effects of Seed Treatment on Yield Components at Cirencester

Seed Treatment (s)	Yield	Ears per m^2	TGW (g)
fludioxonil	3.95	172	41.4
fludioxonil + silthiofam	4.68	201	43.8
fluquinconazole + prochloraz	4.81	194	43.8
fuberidazole + triadimenol	3.60	160	42.2
LSD 5%	1.02	14.0	1.97

Grain yields were lower at Cirencester than at the other locations. The highest ranking seed treatment overall was fludioxonil + silthiofam. However, sites varied and treatment differences were generally not significant.

Table 3 Effect of Location and Seed Treatment on Grain Yield

	Cirencester	Andover	G Carlton	3 Site Mean
fludioxonil	3.95	6.59	7.00	5.85
fludioxonil + silthiofam	4.68	7.07	7.44	6.39
fluquinconazole + prochloraz	4.81	7.01	7.03	6.28
fuberidazole + triadimenol	3.60	6.90	7.06	5.85
Mean	4.26	6.89	7.13	6.09
LSD 5%	1.02	0.47	n.s.	

Take-all was present at all sites, but incidence was highest at Great Carlton. Differences between seed treatments were apparent at only two of the three locations. At Andover, take-all severity in April was significantly lower for fludioxonil + silthiofam and fluquinconazole + prochloraz than for fludioxonil alone. These two treatments also gave the lowest severity at Cirencester (Table 4). By June, differences were small.

Table 4 Effect of Location and Seed Treatment on Take-all Severity at GS31 in April

	Cirencester	Andover	G Carlton	3 Site Mean
fludioxonil	6.2	6.5	10.0	7.6
fludioxonil + silthiofam	1.6	2.8	10.9	5.1
fluquinconazole + prochloraz	1.3	4.2	12.3	5.9
fuberidazole + triadimenol	5.5	5.1	9.5	6.7
LSD 5%	n.s.	2.0	n.s.	

Effects of Seed Rate

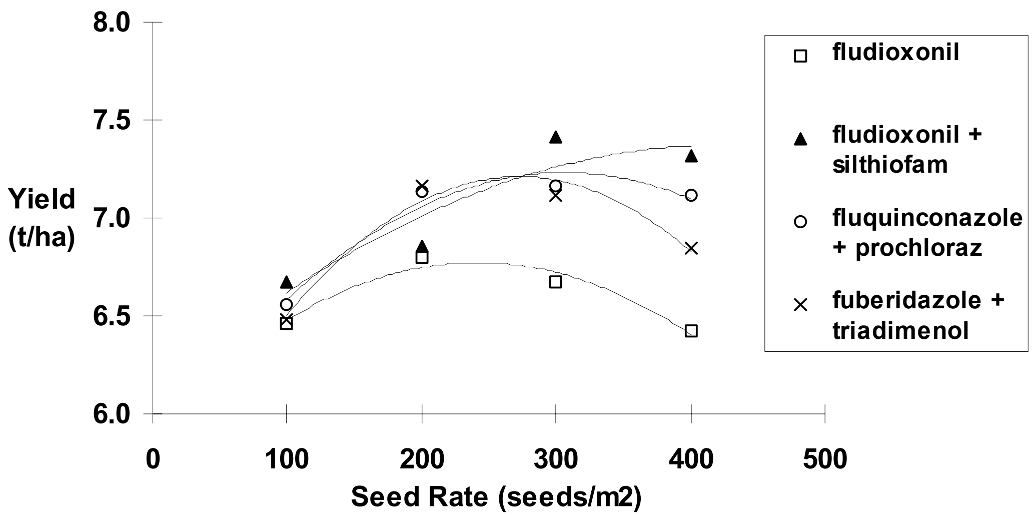
There were significant increases in plant, shoot and ear populations with seed rate at all locations, regardless of seed treatment (Table 5).

Table 5 Effects of Seed Rate on Crop Structure (3 Site Mean)

Seed Rate (seeds/m^2)	Populations (per m^2)		
	Plants	**Shoots**	**Ears**
100	70	161	188
200	136	302	240
300	201	379	275
400	248	428	299

There was evidence of an interaction between seed treatment and rate at Andover, with the other treatments showing a greater yield advantage over fludioxonil at the higher seed rates than at the lower rates (Figure 1).

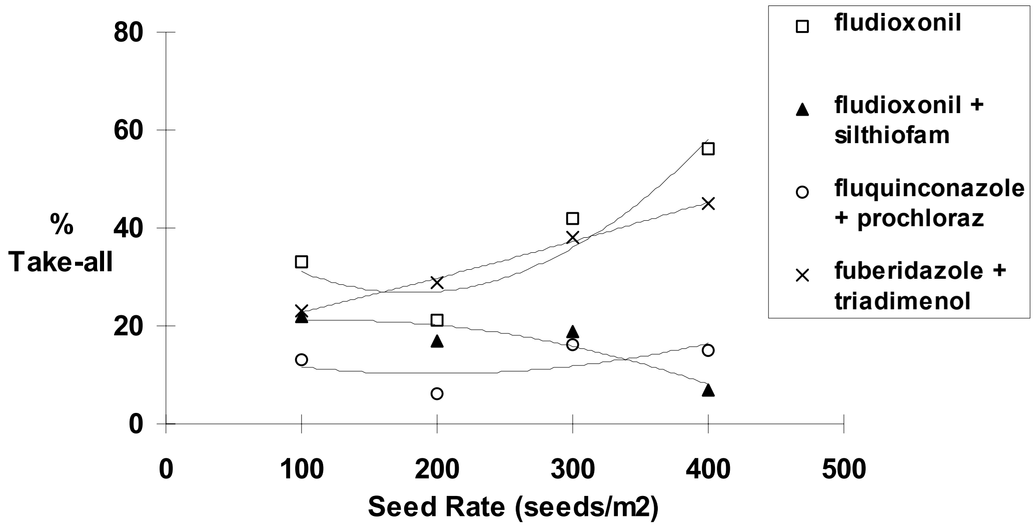
Figure 1 Effect of Seed Treatment on Yield Response to Seed Rate at Andover



Over all sites, the yield penalty from 100 seeds/m^2 compared to the other seed rates ranged from 0.39-0.67 t/ha for fuberidazole + triadimenol, 0.54-0.67 t/ha for fludioxonil, 0.71-1.04 t/ha for fluquinconazole + prochloraz, and 0.87-1.24 t/ha for fludioxonil + silthiofam.

At Cirencester, a higher take-all incidence and severity were recorded at GS31 at the two higher seed rates than at the two lower rates, for both fludioxonil alone and fuberidazole + triadimenol. By comparison, there was little or no increase in take-all as seed rate increased for the other two seed treatments (Figure 2).

Figure 2 Effect of Seed Treatment and Seed Rate on GS31 Take-all Incidence at Cirencester



Economic Analysis

The cost per hectare of a seed treatment depends on the cost per tonne for the treated seed, and the seed rate used. Using typical autumn 2001 prices for untreated seed and the four seed treatments, and assuming a thousand grain weight of 50g, the margin per hectare over the cost of the treated seed can be calculated for each of the combinations for grain prices of £60 and £75 per tonne, and these are summarised in Table 6.

Table 6 Margin over Cost of Treated Seed (£/ha) - 3 Site Mean.

Seed Treatment(s)	Margin over cost £/ha (grain £60/t)				Margin over cost £/ha (grain £75/t)			
	seed rate (seeds/m^2)							
	100	200	300	400	100	200	300	400
fludioxonil	312	338	330	311	393	428	421	400
fludioxonil + silthiofam	319	351	354	317	403	449	457	416
fluquinconazole + prochloraz	319	344	341	329	403	439	440	429
fuberidazole + triadimenol	315	342	312	304	397	434	399	393

For three out of the four seed treatments, there was little difference in margin over cost between the 200 and 300 seeds/m^2 seed rates. The exception was fuberidazole + triadimenol, where 200 seeds/m^2 was superior. Regardless of seed rate or grain price, fludioxonil + silthiofam and fluquinconazole + prochloraz were more profitable than fludioxonil alone.

Comparison with 1998-2000 Results

Table 7 shows the yield response to seed rate and seed treatment (excluding fluquinconazole + prochloraz which was not included in 1998-2000) at Cirencester and Great Carlton in 2001 compared to the nearest equivalent sowing dates in the previous three seasons.

Table 7 Grain Yield Response to Seed Treatment and Seed Rate

Seed Treatment(s)	Seed Rate (seeds/m^2)	Grain Yield as % of fludioxonil 200 seeds			
		Cirencester		Great Carlton	
		98-00 Mean	2001	98-00 Mean	2001
fludioxonil	200	(6.86 t/ha) 100	(4.07 t/ha) 100	(8.99 t/ha) 100	(7.12 t/ha) 100
	300	104	106	101	101
	400	103	105	100	100
fludioxonil + silthiofam	200	102	125	103	106
	300	106	129	105	112
	400	103	118	104	107
fuberidazole + triadimenol	200	98	99	102	102
	300	100	82	104	100
	400	102	94	103	101

At both locations, the 2001 seed rate response for fludioxonil at 200-400 seeds/m^2 was similar to the 1998-200 mean. The trend for fludioxonil + silthiofam was also similar, although the yield increases from silthiofam were larger than the 3 year mean. The performance of fuberidazole + triadimenol was quite different to 1998-2000.

Take-all severity in April was higher at Great Carlton in 2001 than previously, and whilst differences between seed treatments have tended to be smaller at this site, their ranking showed little similarity. In contrast, both severity and seed treatment differences at Cirencester were similar to the 3 year mean. In two out of four years at Cirencester, take-all incidence at GS31 has been substantially greater at 400 than at 200 seeds/m^2 with fludioxonil alone. Only in 1999 was there a small increase at the higher seed rate with fludioxonil + silthiofam.

Table 8 Effects of Seed Rate on GS31 Take-all Incidence at Cirencester

Seed Treatment	Seed Rate (seeds/m2)	Take-all Incidence (%) at GS31				
		1998	1999	2000	2001	Mean
fludioxonil	200	16	12	44	21	23
	400	9	22	46	56	33
fludioxonil + silthiofam	200	3	9	33	17	16
	400	0	12	30	7	12

Conclusions and Implications

Results from 2001 indicate that, like silthiofam, a seed treatment based on fluquinconazole can give partial control of take-all, but the effect appears to diminish as the season progresses. It is not possible to conclude whether the level of take-all control obtained with fluquinconazole + prochloraz is likely to be more similar to that observed over the four years with silthiofam, or with fuberidazole + triadimenol. Differences in take-all severity observed were reflected in grain yields, but the relative performance of the seed treatments differed between sites. In 2001, fuberidazole + triadimenol gave the least consistent advantage over fludioxonil alone.

The impact of seed treatment on shoot and ear populations remains small compared to that of seed rate. However, the effects on establishment observed with fluquinconazole + prochloraz as well as fuberidazole +

triadimenol in 2001, have been recorded in several of the previous trials featuring fuberidazole + triadimenol, notably when drilling on heavier land sites in October.

Seed rate has again been shown to be an important factor in managing second wheats at risk from take-all. Although the lowest seed rate evaluated, 100 seeds/m^2, was below optimum regardless of seed treatment, it should be remembered that one site could not be drilled until November, and both earlier sown locations had poor tillering and low ear populations due to the wet conditions. Further evidence of an interaction between seed treatment and seed rate was provided by the size of the yield penalty associated with the lowest seed rate. This was much greater for fludioxonil + silthiofam or fluquinconazole + triadimenol than for fludioxonil or fuberidazole + triadimenol. However, optimum seed rates were still the same for all seed treatments, with little difference between 200 and 300 seeds/m^2, apart from fuberidazole + triadimenol where 200 seeds/m^2 was best.

Whilst only some of the trials during the past four years have shown an effect of seed rate on take-all levels, results from one location in 2001 again suggest that incidence of the disease in April may be greater at higher than at lower seed rates, particularly where the seed treatment does not give control of take-all. Therefore, although the use of non take-all seed treatment at a higher seed rate might cost less than the use of a take-all seed treatment at a lower seed rate, the increased take-all risk would pose a particular threat to yield.

The Effects of Seed Treatment and Seed Rate on the Impact of Take-all on Second Wheat Grain Yields.

1. Introduction

Crop husbandry is a vital element in managing second wheats to minimise the impact of take-all on yield. In a 3-year HGCA-funded study which preceded this investigation (HGCA Project Report No. 255), it was shown that even when seed treatments are used that can reduce take-all, it is still important to delaying sowing from September until October, and to apply a large enough first dose of nitrogen fertiliser during tillering. However, with the area of wheat being sown on many farms getting larger, an earlier start to second wheat drilling has become necessary, which then increases the take-all threat.

Both seed treatment and sowing date can have significant implications for selecting an appropriate seed rate. In particular, as a chemical applied to the seed, the cost per hectare of the take-all treatments is directly linked to seed rate. The preceding study therefore also examined the effects of seed treatment on response to seed rate, and the resulting take-all impact on grain yield. For seed rates ranging from 200 to 400 seeds/m^2, choice of seed treatment between fludioxonil (Beret Gold), fludioxonil + silthiofam (Beret Gold + Latitude), and fuberidazole + triadimenol (Baytan) did not alter the optimum seed rate for either September or October drilling. However, in some trials take-all incidence was greater at the highest seed rate.

The main objectives of this additional investigation were to extend the range of seed rates evaluated down to 100 seeds/m^2, allowing further evaluation of the cost/benefit relationship for silthiofam treatment, and to include fluquinconazole + prochloraz (Jockey) for comparison over the same range of seed rates.

2. Materials and Methods

2.1 Trial Details

Replicated trials were established to compare four seed treatments at four seed rates on a single winter wheat variety. These were conducted on three second wheat sites at locations with contrasting soil types (Table 2.1). The target sowing date was late September, but wet weather prevented one trial (Andover) from being sown until early November.

Table 2.1 Site Details and Sowing Dates

Location	Soil Type	Sowing Date	Harvest Date
North - Great Carlton, Lincs.	Heavy, fine clay loam	25/09/2000	21/08/2001
South - Andover, Hants.	light, chalkland soil	10/11/2000	14/08/2001
West - Cirencester, Gloucs.	light, limestone brash clay	06/10/2000	23/08/2001

2.2 Seed Treatments and Seed Rates

Application rates for the four seed treatments examined are shown in Table 2.2. A single batch of winter wheat seed (cv. Consort) was used for all treatments at all sites. The seed for each plot was individually weighed, packeted and drilled to achieve seed rates of 100, 200, 300 and 400 seeds/m^2.

Table 2.2 Seed Treatment Application Rates

Active Ingredient (s)	Product (s)	Application Rate
fuberidazole + triadimenol	Baytan Flowable	4.5 + 37.5 g ai / 100 kg seed
fludioxonil	Beret Gold	5 g ai / 100 kg seed
fludioxonil + silthiofam	Beret Gold + Latitude	5 + 25 g ai / 100 kg seed
fluquinconazole + prochloraz	Jockey	75 + 14 g ai / 100 kg seed

2.3 Trial Design and Analysis

Trials were sown to a pre-determined layout, using a randomised split plot design, with seed treatment as the main plot and seed rate as the sub plot. Three replicates were used for yield and grain size measurements, and a further three were sampled for take-all and crop structure assessments. Multi-factor analysis of variance was conducted on all data.

2.4 Assessment Details

Autumn plant population was determined for all treatments at GS13 by counting 6 x 1.0m row lengths per plot. Shoot populations in spring at the end of GS30, and ear populations pre-harvest, were recorded in the same areas, enabling the number of shoots and ears per plant to be calculated.

Root infection with take-all was assessed in April (at GS31) and June (at GS65). At each timing, 4 x 0.25m row lengths were dug at random from each sample plot, avoiding the outside rows. Roots were then washed after excess soil had been removed. Both the incidence (number of plants affected) and severity (percentage of root area affected) of take-all necrosis were recorded. A take-all severity index was then calculated (see appendix A). Fresh grain yields were determined using a plot combine, and these were adjusted for moisture content and plot size to give a yield in tonnes/ha at 15% moisture content. Specific weight (kg/hl) and thousand grain weight (g) were measured from each plot sample.

3. Results

3.1 Grain Yield

Cirencester produced lower grain yields than the other two sites, as has often been the case when comparing these locations in previous trials. The highest yielding seed treatment overall was fludioxonil + silthiofam, although differences between treatments at individual sites were generally not significant. At Great Carlton, silthiofam was the only seed treatment that gave any apparent advantage over fludioxonil alone, compared to Cirencester where fluquinconazole + prochloraz was equally beneficial, and Andover where both fluquinconazole + prochloraz and fuberidazole + triadimenol were advantageous (Table 3.1).

Table 3.1 Grain Yield Response to Seed Treatment and Seed Rate

Seed Treatment(s)	Seed Rate (seeds/m^2)	Grain Yield (t/ha)			
		Cirencester	Andover	G Carlton	3 Site Mean
fludioxonil	100	3.12	6.46	6.60	5.39
	200	4.07	6.80	7.12	6.00
	300	4.33	6.67	7.18	6.06
	400	4.27	6.42	7.10	5.93
	Mean	**3.95**	**6.59**	**7.00**	**5.85**
fludioxonil + silthiofam	100	3.59	6.67	6.64	5.63
	200	5.09	6.86	7.55	6.50
	300	5.23	7.41	7.96	6.87
	400	4.79	7.32	7.59	6.57
	Mean	**4.68**	**7.07**	**7.44**	**6.39**
fluquinconazole + prochloraz	100	3.82	6.56	6.46	5.61
	200	4.84	7.13	6.98	6.32
	300	5.18	7.16	7.33	6.56
	400	5.38	7.20	7.36	6.65
	Mean	**4.81**	**7.01**	**7.03**	**6.28**
fuberidazole + triadimenol	100	3.19	6.48	6.73	5.47
	200	4.04	7.16	7.23	6.14
	300	3.32	7.12	7.13	5.86
	400	3.83	6.85	7.16	5.95
	Mean	**3.60**	**6.90**	**7.06**	**5.85**
seed treatment only	F prob. sed. (d.f.)	0.073 0.415 (6)	0.160 0.192 (6)	0.965 0.985 (6)	
seed rate x treatment	F prob. sed. (d.f.)	0.342 0.412 (24)	0.110 0.207 (24)	0.115 0.312 (24)	

There was an indication of an interaction between seed rate and seed treatment at Andover (Table 3.1). The yield advantage of the other three seed treatments over fludioxonil alone averaged 0.11 t/ha at 100 seeds/m^2, 0.25 t/ha at 200 seeds, 0.56 t/ha at 300 seeds and 0.66 t/ha at 400 seeds/m^2. However, only fludioxonil + silthiofam appeared to have a higher optimum seed rate of 300 seeds/m^2 compared to 200 seeds/m^2 for fludioxonil alone. A similar trend was apparent for fludioxonil + silthiofam at Great Carlton, and for fluquinconazole + prochloraz at Cirencester, but not for fuberidazole + triadimenol at either location.

3.2 Crop Structure and Yield Components

Establishment varied between sites, ranging from an average of 50% at Great Carlton to 80% at Andover Significant plant population increases with seed rate were obtained in all cases (Table 3.2). Although there were no significant differences between seed treatments, at Cirencester establishment averaged 60% for fluquinconazole + prochloraz and fuberidazole + triadimenol, compared to 70% for fludioxonil. At Great Carlton, all four seed treatment gave similar final plant populations, but fluquinconazole + prochloraz and fuberidazole + triadimenol were slower to emerge than either fludioxonil or fludioxonil + silthiofam.

Table 3.2 Effects of Seed Treatment and Seed Rate on Crop Structure (3 Site Mean)

	Populations (per m^2)		
Seed Treatment(s)	**Plants**	**Shoots**	**Ears**
fludioxonil	169	309	231
fludioxonil + silthiofam	169	343	268
Fluquinconazole + prochloraz	154	312	258
fuberidazole + triadimenol	162	306	244
Seed Rate (seeds/m^2)			
100	70	161	188
200	136	302	240
300	201	379	275
400	248	428	299

Shoot and ear populations also increased with seed rate (Table 3.2). One again seed treatment differences were mostly not significant, but highest recorded populations were always either with fluquinconazole + prochloraz or fludioxonil + silthiofam. Regardless of seed rate, fludioxonil alone produced the lowest number of ears per plant, but the effect of seed treatment was small compared to that of seed rate (Table 3.3).

Table 3.3 Effect of Seed Treatment and Rate on Number of Ears per Plant (3 Site Mean)

Seed Rate And Seed Treatment	**Number of Ears per Plant**				
	fludioxonil	fludioxonil + silthiofam	fluquinconazol e + prochloraz	fuberidazole + triadimenol	Mean
100	2.5	2.9	3.1	2.8	2.8
200	1.5	1.9	2.0	1.7	1.8
300	1.3	1.5	1.5	1.4	1.4
400	1.1	1.3	1.4	1.2	1.2
Mean	1.6	1.9	2.0	1.8	

Comparison of the yield components (ear populations and thousand grain weights) and grain yield for the four seed treatments at Cirencester shows a clear relationship between them (Table 3.4):

Table 3.4 Effects of Seed Treatment on Yield Components at Cirencester

Seed Treatment (s)	Yield	Ears per m^2	TGW (g)
fludioxonil	3.95	172	41.4
fludioxonil + silthiofam	4.68	201	43.8
fluquinconazole + prochloraz	4.81	194	43.8
fuberidazole + triadimenol	3.60	160	42.2
F prob. sed. (d.f.)	0.073 0.415 (6)	0.002 5.74 (6)	0.060 0.804 (6)

3.3 Take-all Assessments

Take-all was present at all sites, with an average of 46% (range 25-75%) of plants showing at least one area of black root rot at GS31 in April, and 82% (range 61-98%) at GS65 in June. The highest incidence of take-all was at Great Carlton, which notably was the earliest-sown site. In June, take-all severity was also highest at Great Carlton, and lowest at Andover where sowing was delayed until November. In previous trials, take-all levels have tended to be lower on the heavier land site at Great Carlton than on lighter land sites in the south and south-west of England, where sowing dates have not differed.

Differences between seed treatments were evident at two locations, but not at Great Carlton. At Andover, take-all severity at GS31 was significantly lower for fludioxonil + silthiofam and fluquinconazole + prochloraz than for fludioxonil alone. These two treatments also gave the lowest take-all severity at Cirencester (Table 3.5). By GS65, differences at Andover were small, and only fludioxonil + silthiofam was still showing a benefit at Cirencester.

Table 3.5 Effect of Seed Treatment on Take-all Severity at GS31

Seed Treatment(s)	Take-all Severity Index at GS31		
or Seed Rate (seeds/m^2)	Cirencester	Andover	G Carlton
fludioxonil	6.2	6.5	10.0
fludioxonil + silthiofam	1.6	2.8	10.9
fluquinconazole + prochloraz	1.3	4.2	12.3
fuberidazole + triadimenol	5.5	5.1	9.5
F prob. sed. (d.f.)	0.173 2.325 (6)	0.020 0.817 (6)	0.864 3.528 (6)

At Cirencester, a higher take-all incidence and severity were recorded at GS31 at the two higher seed rates than at the two lower rates with fludioxonil alone and fuberidazole + triadimenol. By comparison, there was little or no increase in take-all as seed rate increased for the other two seed treatments (Table 3.6). For fludioxonil + silthiofam, this difference persisted through to GS65, such that take-all severity was 44% less with the addition of silthiofam at 100 seeds/m^2, but 64% less at 400 seeds/m^2 (Table 3.7).

Table 3.6 Effect of Seed Rate on GS31 Take-all Incidence at Cirencester

Seed Rate and Seed Treatment	Take-all Incidence (%) at GS31				
	fludioxonil	fludioxonil + silthiofam	fluquinconazole + prochloraz	fuberidazole + triadimenol	Mean
100	33	22	13	23	23
200	21	17	6	29	18
300	42	19	16	38	29
400	56	7	15	45	31
Mean	38	16	13	34	0.066
F prob. sed. (d.f.)	0.082 9.34 (6)				4.86 (24)

Table 3.7 Effect of Seed Rate on GS65 Take-all Severity at Cirencester

Seed Rate and Seed Treatment	Take-all Severity at GS65				
	fludioxonil	fludioxonil + silthiofam	fluquinconazole + prochloraz	fuberidazole + triadimenol	seed rate x treatment
100	13.0	7.3	15.7	14.7	
200	10.3	9.3	16.7	13.6	F prob. 0.057
300	16.0	9.7	12.0	15.0	sed. 1.28
400	18.7	6.3	15.7	20.0	(d.f. 24)
Mean	14.5	8.2	15.0	15.8	
F prob. sed. (d.f.)	0.116 2.86 (6)				

All sites were examined for the presence of whiteheads at GS77 in July. However, due to rapid ripening resulting from soil and weather conditions, no differences were observed between treatments.

4. Discussion

4.1 2000/01 Results

The exceptionally wet conditions experienced in autumn and winter 2000, followed by long spells of dry weather between May and July 2001, not surprisingly had a significant impact on field trials conducted during the season (not to mention the effect on many farm crops). Even where sowing was possible on the target date, subsequent variability tended to mask the more subtle effects that might be attributable to differing treatments. Although many of the differences recorded at individual sites were not statistically significant, there were some obvious similarities and contrasts between sites, and further evidence of effects observed in previous seasons.

Despite having the earliest sowing date and the highest take-all levels, the Great Carlton trial appeared to show least benefit from the take-all seed treatments. It should be noted however that the soil type at this location was a heavy clay loam that is prone to waterlogging even in an normal season, and grain yields were lower than would typically be expected for that cropping situation. It is also interesting to note the differences in yield and take-all severity recorded between seed treatments at Andover, even though sowing was delayed until early November, which is recognised as the main cultural defence against the disease.

Clearly, a seed rate of 100 seeds/m^2 would not have been expected to produce the optimum yield when sown in early November, but at the two earlier locations it was equally unsuccessful under the conditions experienced during the season. Poor tillering was a feature at both Cirencester and Great Carlton, resulting in low ear populations and therefore marked responses to seed rate. However, the size of the yield penalty associated with the lowest seed rate was affected by choice of seed treatment. Averaged over the three trials, the yield penalty from 100 seeds/m^2 compared to the other seed rates ranged from 0.39-0.67 t/ha for fuberidazole + triadimenol, 0.54-0.67 t/ha for fludioxonil alone, 0.71-1.04 t/ha for fluquinconazole + prochloraz, and 0.87-1.24 t/ha for fludioxonil + silthiofam. At the same time, as Table 4.1 shows, the yield advantage over fludioxonil alone of the highest ranking seed treatment tended to be greater at 300 or 400 seeds/m^2 than at 100 or 200 seeds/m^2.

Table 4.1 Advantage over fludioxonil of Highest Ranking Seed Treatment at each Location

Location and highest ranking seed treatment	**Yield advantage (t/ha) over fludioxonil at a seed rate of**			
	100 seeds/m^2	**200 seeds/m^2**	**300 seeds/m^2**	**400 seeds/m^2**
Cirencester fluquinconazole + prochloraz	0.70	0.77	0.85	1.11
Andover fludioxonil + silthiofam	0.21	0.06	0.74	0.90
Great Carlton fludioxonil + silthiofam	0.04	0.43	0.78	0.49
Mean yield advantage (t/ha)	0.32	0.42	0.79	0.83

Like fuberidazole + triadimenol, fluquinconazole + prochloraz is a conazole-based seed treatment, and it might therefore be expected to show properties that are more similar to the former than to silthiofam, which is from the hindered silyl amide fungicide group. There were few effects of seed treatment on crop growth this season, but the slight delay in emergence at Great Carlton and the small reduction in establishment at Cirencester, that have previously been recorded with fuberidazole + triadimenol, were apparent with both conazole treatments. However, at Cirencester despite this fluquinconazole + prochloraz had the highest shoot population, and had an ear population similar to fludioxonil + silthiofam, and higher than fuberidazole + triadimenol.

None of the seed treatments appeared to give any reduction in the very high take-all levels experienced at Great Carlton, which might explain the lack of any significant yield benefits. The reason for this is not clear. Both silthiofam and fluquinconazole + prochloraz gave partial control at the other two locations, averaging 66% and 57% reductions in take-all severity respectively at GS31 in April. It is notable, however, that by GS65 control was effectively only 10-15% for both treatments at Andover, and fluquinconazole + prochloraz was no longer showing any reduction compared to fludioxonil at Cirencester. This underlines the role of seed treatments as a means of delaying rather than preventing the development of take-all in the crop.

4.2 Economic Analysis

To be of benefit to wheat growers, seed treatments that are applied for take-all control must not only reduce disease severity and increase yield, but they must also be cost-effective. The per hectare cost of a seed treatment depends on the additional cost per tonne for the treated seed, and the seed rate used. Table 4.2 shows how this might vary for the seed treatments and seed rates used in these trials, based on typical seed treatment prices for autumn 2001, and assuming a thousand grain weight of 50g.

Table 4.2 Effect of Seed Treatment Cost per Tonne and Seed Rate on Cost per Hectare

	Seed Treatment and Approximate Cost (£/ha)			
Seed Rate (seeds/m^2)	**fludioxonil (£44/t)***	**fuberidazole + triadimenol (£87/t)***	**silthiofam (£162/t)***	**fluquinconazole + prochloraz (£170/t)***
100	2.20	4.35	8.10	8.50
200	4.40	8.70	16.20	17.00
300	6.60	13.05	24.30	25.50
400	8.80	17.40	32.40	34.00

* Source: Farmers Weekly Seeds Focus Supplement, 13 July 2001

Using these values, and an untreated seed cost of £180 per tonne, the margin per hectare over the cost of the treated seed can be calculated for each of the seed treatment and seed rate combinations for grain prices of £60 and £75 per tonne (see appendix B). These are summarised (as the mean of the three sites) in Table 4.3.

Table 4.3 Margin over Cost of Treated Seed (£/ha) - 3 Site Mean.

Seed Treatment(s)	Margin over cost £/ha (grain £60/t)				Margin over cost £/ha (grain £75/t)			
	seed rate (seeds/m^2)							
	100	200	300	400	100	200	300	400
fludioxonil	312	338	330	311	393	428	421	400
fludioxonil + silthiofam	319	351	354	317	403	449	457	416
fluquinconazole + prochloraz	319	344	341	329	403	439	440	429
fuberidazole + triadimenol	315	342	312	304	397	434	399	393

For three out of the four seed treatments, there was little difference in margin over cost between the 200 and 300 seeds/m^2 seed rates. The exception was fuberidazole + triadimenol, where 200 seeds/m^2 was superior. Grain price had little effect on the optimum seed rate, although at £75/t 400 seeds/m^2 was generally more cost-effective than 100 seeds/m^2, whereas at £60/t this was not the case. Regardless of seed rate or grain price, fludioxonil + silthiofam and fluquinconazole + prochloraz were more profitable than fludioxonil alone. Overall fuberidazole + triadimenol was similar to fludioxonil, and any advantage with fuberidazole + triadimenol at the two lower seed rates was reversed at the higher rates.

4.3 Comparison with 1997/98, 1998/99 and 1999/2000 Seasons

Table 4.4 shows the yield response to seed rate and seed treatment (excluding fluquinconazole + prochloraz which was not included in 1998-2000) at Cirencester and Great Carlton in 2001 compared to the previous three seasons. For best comparison with 2001, the 1998-2000 mean for Cirencester is based on the October sowing date, whereas Great Carlton is based on the mean of the September and October sowing dates.

Table 4.4 Grain Yield Response to Seed Treatment and Seed Rate

Seed Treatment(s)	Seed Rate (seeds/m^2)	Grain Yield t/ha (and % of fludioxonil 200 seeds)			
		Cirencester		Great Carlton	
		98-00 Mean	2001	98-00 Mean	2001
fludioxonil	100	n/a	3.12 (77)	n/a	6.60 (93)
	200	6.86 (100)	4.07 (100)	8.99 (100)	7.12 (100)
	300	7.16 (104)	4.33 (106)	9.06 (101)	7.18 (101)
	400	7.06 (103)	4.27 (105)	8.98 (100)	7.10 (100)
	Mean	**7.03**	**3.95**	**9.01**	**7.00**
fludioxonil + silthiofam	100	n/a	3.59 (88)	n/a	6.64 (93)
	200	6.98 (102)	5.09 (125)	9.23 (103)	7.55 (106)
	300	7.26 (106)	5.23 (129)	9.45 (105)	7.96 (112)
	400	7.04 (103)	4.79 (118)	9.35 (104)	7.59 (107)
	Mean	**7.09**	**4.68**	**9.34**	**7.44**
fuberidazole + triadimenol	100	n/a	3.19 (78)	n/a	6.73 (95)
	200	6.71 (98)	4.04 (99)	9.18 (102)	7.23 (102)
	300	6.83 (100)	3.32 (82)	9.37 (104)	7.13 (100)
	400	7.01 (102)	3.83 (94)	9.24 (103)	7.16 (101)
	Mean	**6.85**	**3.60**	**9.26**	**7.06**

At both Cirencester and Great Carlton the seed rate response for fludioxonil at 200-400 seeds/m^2 in 2001 was similar to the 1998-2000 mean. The trend for fludioxonil + silthiofam was also similar, with yield peaking at 300 seeds/m^2 in all cases. However, the yield benefits from silthiofam in 2001 were greater than the 3 year means for comparable sowing dates. The performance of fuberidazole + triadimenol in 2001 was quite different to 1998-2000, with relative yield declining above 200 seeds/m^2 rather than improving as previously.

In 2001, as in the three previous years, the effects of seed treatment on shoot and ear populations were small compared to the effects of seed rate. Nevertheless, where any differences have been observed, the tendency has been for fludioxonil + silthiofam to have higher numbers than fludioxonil alone. The slightly reduced level of establishment observed at Cirencester with fluquinconazole + prochloraz as well as fuberidazole + triadimenol, has also been observed with the latter in several of the previous trials, but more often on the heavy land sites.

In Table 4.5, take-all levels at Cirencester and Great Carlton in 2001 are compared with the equivalent 1998-2000 means. Severity at GS31 was higher at Great Carlton in 2001 than for similar timings in previous years. Differences between seed treatments have tended to be smaller at this site than at other locations, and whereas Cirencester is showing a fairly similar treatment ranking in 2001 to previously, Great Carlton is not.

Table 4.5 Effects of Seed Treatment on Take-all Severity at GS31 in April

Seed Treatment(s)	Take-all Severity Index at GS31			
	Cirencester		Great Carlton	
	98-00 Mean	2001	98-00 Mean	2001
fludioxonil	4.05	6.2	3.26	10.0
fludioxonil + silthiofam	1.63	1.6	2.02	10.9
fuberidazole + triadimenol	3.27	5.5	2.78	9.5
fluquinconazole + prochloraz	n/a	1.3	n/a	12.3

In two out of the four years at Cirencester, take-all incidence at GS31 has been substantially greater at 400 seeds/m^2 than at 200 seeds/m^2 with fludioxonil alone (levels at other seed rates were not assessed prior to 2001). Only in 1999 was there an increase at the higher seed rate with fludioxonil + silthiofam, and even this was small. Similar differences have been observed in some of the other trials during the four year period, but there is no consistent pattern to these.

Table 4.6 Effects of Seed Rate on GS31 Take-all Incidence at Cirencester

Seed Treatment	Seed Rate (seeds/m2)	Take-all Incidence (%) at GS31				
		1998	1999	2000	2001	Mean
fludioxonil	200	16	12	44	21	23
	400	9	22	46	56	33
fludioxonil + silthiofam	200	3	9	33	17	16
	400	0	12	30	7	12

5. Conclusions and Implications

Results from 2001 indicate that, like silthiofam, a seed treatment based on fluquinconazole can give partial control of take-all. However, comparison of assessments in April and June suggest that as with silthiofam the effect diminishes as the season progresses. It should also be noted that at one location this year seed treatment appeared to have no effect on take-all levels. From these results alone, it is not possible to conclude whether the level of take-all control obtained with a fluquinconazole + prochloraz is likely to be more similar to that observed over the four years with silthiofam, or with fuberidazole + triadimenol.

The differences in take-all severity observed at two of the locations were reflected in grain yields. The relative performance of seed treatments differed between sites, but overall fuberidazole + triadimenol gave the least consistent advantage over fludioxonil in 2001, and was less beneficial than in the previous three years. Seed rate had a significant effect upon yield, with 100 seeds/m^2 below optimum regardless of seed treatment. However, this would have been expected as one of the sites could not be drilled until November, and at both the earlier sown locations poor tillering and low ear populations resulted from the wet conditions.

The impact of seed treatment on shoot and ear populations remains small compared to that of seed rate. The effects on establishment, observed with fluquinconazole + prochloraz as well as fuberidazole + triadimenol in 2001, have though been observed in several of the previous trials featuring fuberidazole + triadimenol. This has tended to be on the heavier land sites, where drilling has taken place in wet conditions in October.

Further evidence of an interaction between seed treatment and seed rate in the presence of take-all was provided by the size of the yield penalty associated with the 100 seeds/m^2 rate. This was much greater for fludioxonil + silthiofam or fluquinconazole + prochloraz than for fuberidazole + triadimenol or fludioxonil, reflecting both their effectiveness against take-all and their overall yield ranking. Despite this, due to their higher cost, the optimum seed rates for fludioxonil + silthiofam or fluquinconazole + prochloraz were the same as for fludioxonil, with little difference between 200 and 300 seeds/m^2. Fuberidazole + triadimenol was less cost-effective at 300 than at 200 seeds/m^2 in 2001, but has not recorded a lower optimum in previous years.

Whilst only some of the trials during the past four years have shown an effect of seed rate on take-all levels, results from one location in 2001 again suggest that the incidence of take-all in April may be greater at higher than at lower seed rates, particularly where the seed treatment does not give control of take-all. This would offer an explanation for the yield differences mentioned above.

Seed treatment and seed rate are clearly important considerations in the management of second wheats at risk from take-all. Levels of the disease, yield and margin over cost can all be affected. Although the use of a non take-all seed treatment at a higher seed rate might cost less than the use of a take-all seed treatment at a lower seed rate, far from recouping some of the yield loss due to take-all a high seed rate may simply depress yields even further. Whatever the choice of seed treatment, it is still vital to delay drilling wherever possible from September until October at the earliest. in order to reduce the take-all risk. Seed rates will therefore need to be adjusted to take into account sowing date, soil type and seedbed conditions.

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Appendices

Appendix A

Formulae for Calculation of Take-all Incidence and Severity Index

The severity of root necrosis on each plant was recorded by category as follows

Category	% Root area affected
0	0
1	1-10
2	11-30
3	31-60
4	61-100

Incidence of Take-all was calculated as: $\dfrac{\text{Number of plants with Take-all}}{\text{Number of plants assessed}} \times 100\ \%$

Take-all **Severity Index** was calculated as: $\dfrac{(0 \times a) + (10 \times b) + (30 \times c) + (60 \times d) + (100 \times e)}{\text{Total number of plants}}$

where a, b, c, d and e are the number of plants in categories 0, 1, 2, 3 and 4 respectively

Appendix B

Table of Margins over Cost of Treated Seed

Seed Treatment	Seed rate seeds/m 2	Yield (t/ha)	Output Value (£/ha)		Seed cost (£/ha)	MOC treat seed (£/ha)	
			grain £60/t	grain £75/t		grain £60/t	grain £75/t
fludioxonil	100	5.39	323.40	404.25	11.20	312.20	393.05
	200	6.00	360.00	450.00	22.40	337.60	427.60
	300	6.06	363.60	454.50	33.60	330.00	420.90
	400	5.93	355.80	444.75	44.80	311.00	399.95
fludioxonil + silthiofam	100	5.63	337.80	422.25	19.30	318.50	402.95
	200	6.50	390.00	487.50	38.60	351.40	448.90
	300	6.87	412.20	515.25	57.90	354.30	457.35
	400	6.57	394.20	492.75	77.20	317.00	415.55
fluquinconazole + prochloraz	100	5.61	336.60	420.75	17.50	319.10	403.25
	200	6.32	379.20	474.00	35.00	344.20	439.00
	300	6.56	393.60	492.00	52.50	341.10	439.50
	400	6.65	399.00	498.75	70.00	329.00	428.75
fuberidazole + triadimenol	100	5.47	328.20	410.25	13.35	314.85	396.90
	200	6.14	368.40	460.50	26.70	341.70	433.80
	300	5.86	351.60	439.50	40.05	311.55	399.45
	400	5.95	357.00	446.25	53.40	303.60	392.85

Based on untreated seed at £180/t, fludioxonil seed treatment at £44/t, silthiofam at £162/t, fuberidazole + triadimenol at £87/t, fluquinconazole +prochloraz at £170/t, a thousand grain weight of 50g, and grain prices of £60/t and £75/t