PROJECT REPORT No. 280

NITROGEN MANAGEMENT IN SECOND WHEATS FOLLOWING STROBILURIN FUNGICIDE PROGRAMMES

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NITROGEN MANAGEMENT IN SECOND WHEATS FOLLOWING STROBILURIN FUNGICIDE PROGRAMMES

by

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ABSTRACT

Strobilurins are a group of cereal crop fungicides, which may have a positive effect on crop yield beyond disease control. They increase yield by prolonging canopy duration, and thereby nitrogen uptake. It has been feared that this increased nitrogen offtake (10 – 40 kg ha^{-1}) may reduce soil nitrogen reserves for following crops, and that extra nitrogen may have to be applied to compensate for this shortfall. This project followed the nitrogen dynamics of first and second year wheat crops on three soil types. The first year crops were treated with two types of strobilurin and a traditional fungicide, and also had three levels of nitrogen fertiliser (0, 160 & 320 kg ha^{-1} N) applied. The second year wheat was not fertilised, and had a uniform fungicide programme.

First year wheat:

- Strobilurin fungicides produced a marginal yield enhancement above traditional fungicides (0.1 – 0.7 t ha^{-1}) on clay loam and silty clay loam soils.
- The yield enhancement was largely due to an increase in grain size.
- No increase in nitrogen offtake was recorded at any site due to strobilurin use.
- Mineral nitrogen levels in the soil after harvest were not depleted after strobilurin use relative to traditional fungicides at any site.
- Excessive nitrogen fertiliser application above the economic optimum, left large quantities of nitrogen in the soil after harvest, but did not enhance yields.

Second year wheat:

- Excessive rainfall of twice the long-term average during the establishment phase led to higher than normal leaching and poor crop establishment on clay loam and silty clay loam soils.
- Soil mineral nitrogen in the soil during the spring was not reduced by the preceding use of strobilurins.
- The excess nitrogen left in the soil by high applications of fertiliser in the preceding year, had largely been leached from all the soils, but left an enhanced residue on clay loam and silty clay loams.
- Excess nitrogen from the application of large amounts of fertiliser nitrogen applied in the first year produced enhanced yields (0.5 – 1.5 t ha^{-1}), due to a similar enhancement of soil nitrogen supply.
- The incorporation of straw reduced this enhancement by immobilising soil nitrogen.
- There was no reduction of soil nitrogen supply or yield, due to strobilurin use in the first year.

No change in the management of crop nitrogen nutrition in second wheats can be recommended as necessary for crops following those treated with strobilurin fungicides. However, the excessive use of nitrogen fertilisers above the economic optimum, conveys no benefit in its year of use and only marginal benefit in the following year, but does contribute to an environmentally damaging leachate to waterways, and should be avoided.

SUMMARY

Introduction

It has now become fairly well established that when compared with more traditional chemistry fungicides, strobilurin fungicides can convey a yield advantage on cereals over and above that merely due to disease control. The physiological mechanisms by which this operates are becoming known and one component of these is enhanced nitrogen assimilation and utilisation for protein synthesis. It has been noticed in past ADAS experiments and elsewhere that there was sporadic evidence for greater nitrogen uptake by cereals late in the season during a prolonged period of green leaf persistence before grain filling. This effect was of the order of 10 – 50 kg ha^{-1} extra nitrogen offtake, but not found consistently, or tested for over a wide range of sites. An attendant observation was that soil mineral nitrogen at harvest was slightly depleted as a consequence, and that this would lead to a similarly depleted supply of soil nitrogen to a following cereal crop.

Experiments were therefore set up with the objectives of: investigating changes in the nitrogen balance between crop and soil over two winter wheat cropping seasons, following applications of triazole and strobilurin fungicides in the first season; and trying to establish guidelines for nitrogen management in second wheats following the use of strobilurin fungicides in the first season. The experiments were run over three sites of contrasting soils, which were nevertheless typical of land used for cereals, and carried out with both straw incorporated into the soil after the first harvest, as well as baled and removed from the site.

Methods

Three levels of nitrogen fertiliser were applied as treatments N1, N2 and N3; namely 0, 160 and 320 kg ha^{-1} N in the first year. These were to observe whether reduced or excessive nitrogen exacerbated the effects, of three fungicide treatments applied across these treatments. The fungicide applications were; (F1), a non-strobilurin treatment of “Opus” (triazole) and “Patrol” (morpholine) fungicides; (F2) “Opus” and “Amistar” (azoxystrobin) fungicides; and (F3) “Opus” and “Twist” (trifloxistrobin) fungicides, applied at typical dose rates. These treatments were only applied in the first year, and a second wheat was sown into the experimental plots as a test crop. No nitrogen fertiliser at all was applied to this second wheat, and a uniform prophylactic fungicide programme was applied uniformly across all experiments.

Crop yields were measured in both years as well as the contributing component parameters of that yield (such as ear numbers, grain number per ear and thousand grain weights). Soil and crop nitrogen dynamic parameters were also measured in both years such that the total soil nitrogen supply (SNS) could be

calculated for each crop. These included spring and harvest soil mineral nitrogen concentrations (to 90 cm depth) as well as grain and straw nitrogen concentrations at harvest.

Results and Discussion

The yield enhancement conveyed by strobilurin fungicides (F2 & F3) found at Terrington, was not repeated in the first year of these experiments at any site ($P<0.05$), though fungicide treatments F2 & F3 were marginally higher than F1 at Boxworth (and F3 higher than F1 at Terrington) (Fig. 1). The marginal increase in yields over the triazole only fungicide programme conveyed by both strobilurin programmes, 0.1 0.7 t ha^{-1} was of the same order as that noticed in former trials at Terrington (Bryson, 2000), but proved not to be statistically significant, and clearly there was no effect on the shallow soil at Bridgets.

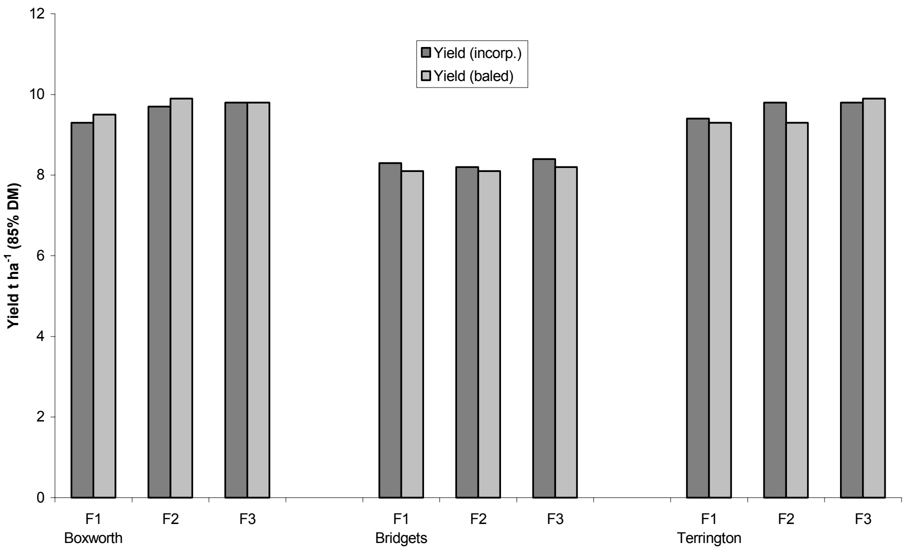

Fig. 1 Mean yields (t ha^{-1}) found at each site and straw incorporation experiment for fungicide treatments (F1 – F3) applied in the first year.

The only parameter which indicated a statistically significant difference due to fungicide treatment in this first year was the thousand grain weight (TGW)(g), which was higher in the F2 & F3 treatments at Boxworth across both straw experiments ($P<0.001$) and also across the baled straw experiment at Terrington (Fig. 2). It seems that any yield enhancing effect of strobilurin applications due to extra nitrogen uptake in the latter part of the growing season is exerting its influence through grain size.

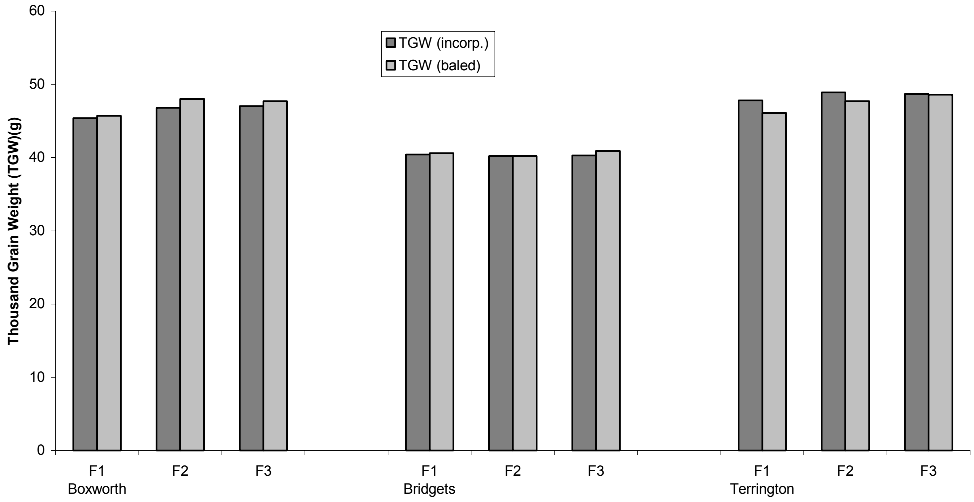

Fig. 2 Mean thousand grain weights (g) found at each site and straw incorporation experiment for fungicide treatments (F1 – F3) applied in the first year.

Previous work had also found that the yield enhancement by strobilurin use also resulted in significantly higher nitrogen offtake from the site, especially comparing the yield of Amistar + Opus treated crops with Opus only (Bryson, 2000). In these experiments no difference in grain N offtake was found to be statistically significant, though the same combination of fungicides (F2) showed some increase over F1 at Boxworth, and the use of Twist instead of Amistar (F3) produced the same minor effect. The order of increase however, was only of the order of 2 –5 kg, whereas before it was 4 – 26 kg over the same range of nitrogen treatments.

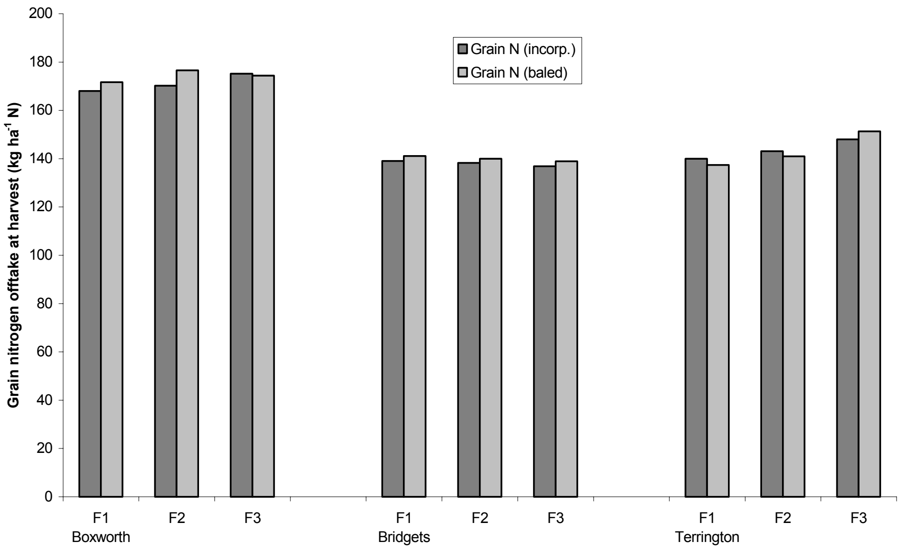

Fig. 3 Mean grain nitrogen offtake (kg ka^{-1}) at each site and straw incorporation experiment for fungicide treatments (F1 – F3) applied in the first year.

The nitrogen treatments produced the large effect on yields (Fig. 4) and grain N offtake of first year wheat, which were entirely predictable, but they did not show any statistical interaction with the fungicide treatments. The doubling in nitrogen application between treatments N2 and N3 was shown to be entirely uneconomic with only very minor effect (Sylvester-Bradley *et al.,* 1984), but did leave a large pool of residual mineral nitrogen in these treatments after the first harvest (Fig. 5). There was no difference in this pool between fungicide treatments however.

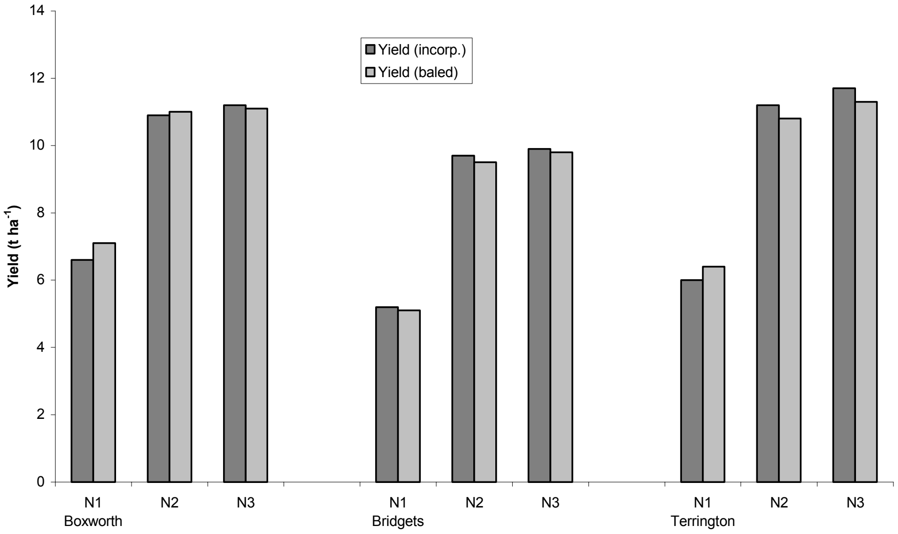

Fig. 4 Mean yields (t ha^{-1})(85% DM) found at each site and straw incorporation experiment for nitrogen treatments (N1 – N3) applied in the first year.

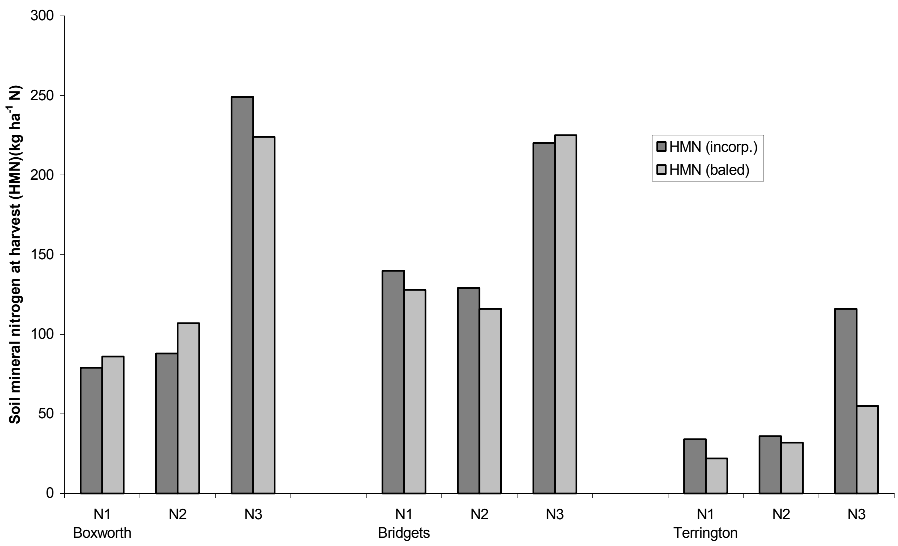

Fig. 5 Mean soil mineral nitrogen left after first year harvest (HMN) (kg ha^{-1} N) found at each site and straw incorporation experiment for nitrogen treatments (N1 – N3) applied in the first year.

Nor was there a statistically significant difference between fungicide treatments in the soil mineral nitrogen on the sites in the following spring, though some of the differences due to nitrogen treatment had been retained (Fig. 6). However, the 50 – 100 kg ha-1 N difference between N3 and N1 & N2 seen in the first year HMN (Fig. 5) had largely been eradicated by over winter leaching (compare Figs. 5 & 6).

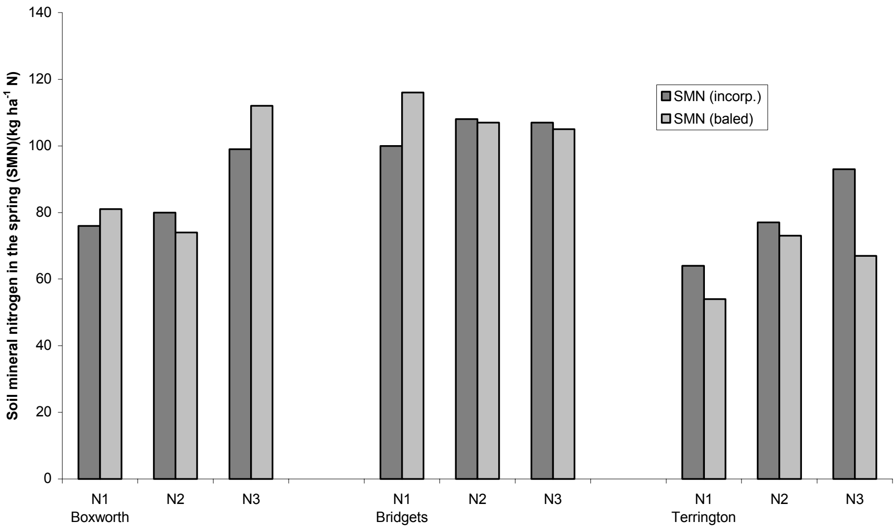

Fig. 6 Mean soil mineral nitrogen left in the spring (SMN) (kg ha^{-1} N) found at each site and straw incorporation experiment in the spring of the second year following nitrogen treatments (N1 – N3) applied in the first year.

The impact of over winter leaching and water-logging were seen quite dramatically in the over-all yield figures, which were severely reduced at Boxworth and Terrington (Fig. 7). Both of these sites are clay loams susceptible to a reduction in working days or physical damage to seedbeds by excess rainfall in the autumn and early winter, and indeed they received 158 and 126 mm above the long term average during the period from September to December when the second wheat crop should have been established. This had the effect of both increasing nitrogen leaching, but also caused a delay in sowing at Boxworth and crop failure at Terrington, which required re-sowing in the following January.

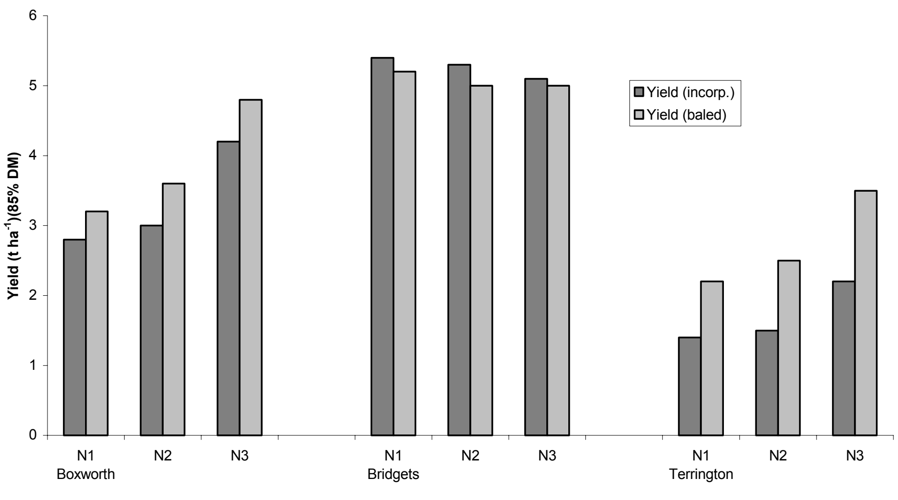

Fig. 7 Mean yields (t ha^{-1})(85% DM) found at each site and straw incorporation experiment of second year wheat for nitrogen treatments (N1 – N3) applied in the first year.

The combination of unexpectedly high leaching pressure, and an unforeseen limitation placed upon the crops potential to take up early nitrogen, because of absent or immature root systems meant that the ability of the crop to take up adequate nitrogen at Boxworth and Terrington sites in particular was much reduced. This was seen in the overall total soil nitrogen supply values calculated for the second year (Fig.8) but also meant the ability of the experiments to discriminate for small carried over effects of residual nitrogen was severely compromised.

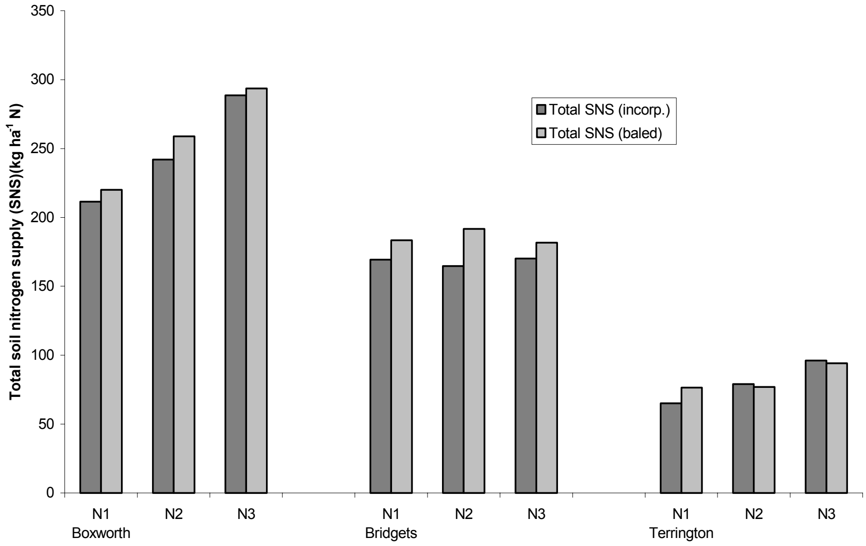

Fig. 8 Mean total soil nitrogen supply (SNS) (kg ha^{-1} N) for at each site and straw incorporation experiment during the second year following nitrogen treatments (N1 – N3) applied in the first year.

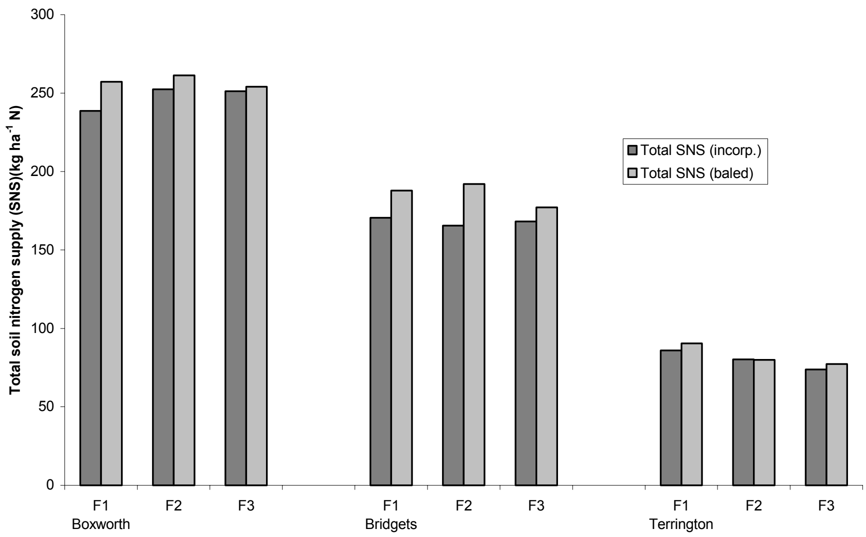

Fig. 9 Mean total soil nitrogen supply (SNS) (kg ha^{-1} N) for at each site and straw incorporation experiment during the second year following fungicide treatments (F1 – F3) applied in the first year.

Differences between nitrogen treatments were highly significant for both experiments at Boxworth ($P<0.001$) and Terrington ($P<0.01$), but for neither at Bridgets in the second year. There was no difference detected for total SNS across fungicide treatments for any experiment in the second year (Fig.9), nor was any sub-significant trend visible. This is counter to previous findings at Terrington, where about 20 and 70 kg ha^{-1}N less soil N was supplied after 160 and 320 kg ha^{-1} N applied in the previous year, when Amistar + Opus (F2) was used, compared with Opus on its own (F1).

Conclusions

Some evidence was found for yield enhancement in first wheats from the use of both azoxystrobin and trifloxistrobin fungicides (over and above any disease suppression) on a site and soil type different to that where the effect was previously noticed (Jones *et al.,* 1998; Bryson, 2000). This yield increase was chiefly attributable to larger grain in crops treated with strobilurins. However, no further evidence was gained that this yield increase was due to extra nitrogen uptake, or that it led to less residual nitrogen for following crops. Any difference in residual nitrogen that may have been created was clearly insufficient to survive a high level of over-winter leaching.

The unfortunate circumstance of this series of experiments was that they were carried out over one of the wettest autumn and early winter periods in recent years, when approximately twice the long-term average rainfall was received on each of the three sites. This led to crop failure and very poor establishment at two of the sites, as well as excessive leaching pressure. In this situation the experiments cannot be viewed as a definite test of the hypothesis underlying the objectives of the experiment (that strobilurin use increases nitrogen uptake in the first year leaving less residual nitrogen in the following year). Equally, however, no recommendations can be made regarding management of second wheats following strobilurin usage with respect to nitrogen fertiliser strategy.

The application of excessive amounts of nitrogen in the first year, gave no yield advantage to that crop, and did not convey a particularly large advantage to a following crop from residual nitrogen. It did, however, leave a large amount of mineral nitrogen open to leaching during the early winter period. The incorporation of straw did little to ameliorate this, and even reduced the nitrogen supply to a following crop further. For these reasons the over supply of nitrogen must be seen as “bad practice” and environmentally damaging, not merely uneconomic.

TECHNICAL DETAIL

Introduction

Strobilurin fungicides have been freely marketed as being fungicides with "added value". This has been seen in the form of increased yield potential from direct effects of strobilurins on cereal physiology, chiefly in the areas of photosynthesis (both solar energy conversion and CO_2 metabolism), the synthesis of starch, increased nitrate reductase activity and improved water utilisation. Commonly the overall effect is seen as an extended period of green leaf at the start of grain filling (Jones & Bryson, 1998) and increased nitrogen uptake at this time.

A definite yield and N offtake increase from strobilurin treated plots, compared with triazole and untreated plots, was recorded in projects at ADAS Terrington in 1997 & 1998 (Bryson, 2000). This same project indicated an offtake differential of 11 - 50 kg ha^{-1} N which may have a knock-on effect for subsequent crops, in that soil nitrogen residues may be reduced *pro rata*. Crop uptake of applied fertiliser nitrogen is typically only about 70 % efficient and excess nitrogen remains in the soil as organic nitrogen, which is open to re-mobilisation in the autumn and following spring, and can contribute considerably to the nitrogen fertility of a following crop (Sylvester-Bradley, 1996). A follow-up study on the above trials at ADAS Terrington revealed a distinct connection between the amount of N offtake in 1998 and the soil nitrogen supply (SNS) for a second year wheat in 1999 (Bryson, 2000). When yields were low in 1998 due to a high incidence of disease, SNS in 1999 was commensurately high, and conversely lower SNS values were measured following high yielding crops treated with strobilurin fungicides (Bryson, 2000). Furthermore, the yield, specific weight and grain nitrogen content of the second year wheat following the strobilurin treatment, were also reduced compared with the triazole only crop.

The preliminary evidence therefore, from one set of experiments on a nitrogen retentive silty clay loam soil, was that the use of strobilurins fungicides delayed senescence, leading to prolonged and extra nitrogen uptake by the crop. This in turn led to lower SNS for a following second year wheat crop, and gave lower yields than a comparable crop with a triazole only fungicide treatment. The was no evidence from these restricted studies as to the mechanism of this effect, though it was suggested that greater amounts of straw incorporated after strobilurins may have increased the soil C:N ratio for the following crop; nor was it known whether the same effect would be noticeable on other less N retentive soils.

The study described in this report was set up over three contrasting soil types to answer such questions, with a view to making recommendations for N management of second wheats following strobilurin fungicides. The work of Sylvester-Bradley (1996) suggests that on retentive soils where first wheats have been either over or under fertilised, an adjustment of 0.1 kg kg^{-1} N on the following crop's fertiliser requirement can be made. In further informing us of the effects of strobilurin fungicides on soil nitrogen dynamics the results of this study should help growers make better decisions regarding the costs and optimum management of second wheats and their likely quality.

Objectives

The specific scientific objectives of the experiments were:

- To investigate changes in the nitrogen balance between crop and soil on three soil types, over two winter wheat cropping seasons, following applications of triazole and strobilurin fungicides in the first season.
- To establish guidelines for nitrogen management in second wheats following the use of strobilurin fungicides in the first season.

Materials & Methods

The study was run as two parallel experiments on each of three sites, at ADAS Boxworth, ADAS Bridgets and ADAS Terrington, soil details of which are given in Table 1. The difference between the two experiments was that straw from the first wheat was incorporated into the soil in one experiment, and baled and removed from the site in the other. The two experiments are thus known respectively as the "Incorporated" and "Baled" experiments in this report.

Table 1 Sites and soils over which experiments were run (figures in parentheses are fertility index levels)

Site	Soil Series	Description
ADAS Boxworth (OS TL 347626)	Hanslope	Clay loam over clay loam. Deep, well structured glacial till. (Hodge *et al.,* 1984)(pH 8.0, K (3), P (3))
ADAS Bridgets (OS SU 518338)	Andover	Shallow silty clay loam over chalk at 40-60 cm depth. (Jarvis *et al.,* 1984)(pH 8.1, K (2) P (2))
ADAS Terrington (OS TF 549196)	Newchurch	Silty clay over silty clay. Deep marine alluvium. (Hodge *et al.,* 1984)(pH 7.8,)

Experimental Layout

Thus there were six experiments in total, two at each of three sites. Each of these experiments was laid out as a randomised block design with three nitrogen treatments, three fungicide treatments and four replicates, and run over two years of winter wheat crops. Treatments were only imposed on the plots in the first year, and after harvest the straw from the crop was either baled and removed, or ploughed into the plots according to which of the two parallel experiments on each site the plots belonged to. The three nitrogen treatments applied were zero N (N1), 160 kg ha^{-1} N (N2) and 320 kg ha^{-1} N (N3) applied as ammonium nitrate prills in three applications of 40 or 100 kg in early April, 60 or 120 kg in mid/late April and 60 or 100 kg in early May (according to whether N2 or N3). Exact dates of application are given in Tables 2, 3 &4, which also contain other husbandry management details of the three sites Boxworth, Bridgets and Terrington respectively.

Across the nitrogen treatments, three fungicide treatments were applied. These consisted of; (F1) a non-strobilurin treatment of “Opus” (triazole) and “Patrol” (morpholine) fungicides at total dose rates of 2.0 and 1.5 L ha^{-1} respectively; (F2) “Opus” and “Amistar” (azoxystrobin) fungicides at total dose rates of 0.75 and 2.0 L ha^{-1} respectively; and (F3) “Opus” and “Twist” (trifloxistrobin) fungicides at total dose rates of 0.75 and 4.0 L ha^{-1} respectively. The doses were applied in three equal amounts at growth stages GS31/32, GS33 and GS39 for all treatments.

In the second year of the experiments, no nitrogen was applied at all, and the fungicide treatment applied uniformly across all plots on each site was that detailed in Tables 2, 3 and 4.

Table 2 *Site management details for experiments at ADAS Boxworth.*

Management activity	**Year 1 (1999/2000)**	**Year 2 (2000/2001)**
Wheat cultivar	Napier	Malacca
Seed rate	150 kg ha^{-1}	230 kg ha^{-1}
Date sown	13/10/99	14/12/00 *Broadcast and harrow*
Dates of N treatment application	27/04/00 (1&2) & 04/05/00	N/A
Growth regulator used	Stefes CCC700	
Herbicides applied	Hawk, IPU, Ally Express, MSS Optica, Starane, Topik	Hawk, Lexus
Insecticides applied	Toppel	Dursban
Fungicides other than treatments	N/A	Landmark (22/05/01 & 05/06/01), Folicur (18/06/01)
Dates of fungicide treatments	08/05/00, 22/05/00 & 09/06/00	N/A
Harvest date	30/08/00	16/08/01

Table 3 Site management details for experiments at ADAS Bridgets.

Management activity	Year 1 (1999/2000)	Year 2 (2000/2001)
Wheat cultivar	Soisson	Consort
Seed rate	225 kg ha^{-1}	185 kg ha^{-1}
Date sown	28/10/99	01/10/00
Dates of N treatment application	27/04/00 (1&2) & 08/05/00	N/A
Growth regulator used		5C Chlormequat
Herbicides applied	Starane, IPU, Panther	Panther, IPU, Starane
Insecticides applied	Cypermethrin	Cypermethrin
Fungicides other than treatments	N/A	Amistar (08/06/01), Landmark (08/06/01) & Folicur (27/06/01)
Dates of fungicide treatments	5, 12 & 22/05/00	N/A
Harvest date	10/08/00	29/08/01

Table 4 *Site management details for experiments at ADAS Terrington.*

Management activity	**Year 1 (1999/2000)**	**Year 2 (2000/2001)**
Wheat cultivar	Consort	*Consort (failed)* and Claire
Seed rate	150 kg ha^{-1}	*180 kg ha^{-1}* and 250 kg ha^{-1}
Date sown	14/10/99	*02/11/01 (failed)* and 17/01/01
Dates of N treatment application	19/04/00 (1), 05/05/02 (2) & 11/05/00	N/A
Growth regulator used	3C Cycocel	3C Cycocel
Herbicides applied	Starane, Stefes, Tolkan	Harmony, Optica
Insecticides applied	Toppel	Aphox
Fungicides other than treatments	N/A	Landmark (23/05/01), Landmark (04/06/01) & Folicur (05/07/01)
Dates of fungicide treatments	01, 17 & 31/05/00	N/A
Harvest date	22/08/00	29/08/01

Sampling programme.

Both crop and soil parameters were measured to determine the nitrogen dynamics from all plots.

Soil samples were taken to a depth of 90cm by coring, in both the spring (SMN-S) and after harvest (SMN-H) in each year. From each plot six cores were taken and bulked together, for successive depth layers of 0-30, 30-60 and 60-90 cm. The bulked samples were then analysed for mineral nitrogen (sum of ammonium and nitrate nitrogen) concentrations according to standard laboratory assays. The exact dates of sampling are given in Tables 2, 3 & 4.

Crop sampling was carried out at harvest in both years, from two 0.5 m^2 quadrats in each plot. Samples were analysed for shoot, ear and grain numbers, thousand grain weights (g), and grain yield (t ha^{-1}) as well as total shoot biomass (t ha^{-1})(not shown) for each plot. Sub-samples of grain, chaff and straw were also analysed for total nitrogen content (% g g^{-1} N). Biomass (not shown) and nitrogen harvest indices were also calculated from these results, as were the grain N offtake (kg ha^{-1} N) and total N offtake (kg ha^{-1} N). Undisturbed strips from each plot were combine harvested for yields (t ha^{-1} at 85% DM).

The ability of each site to supply nitrogen to the crop was assessed by calculating the soil nitrogen supply (SNS), which consists of the nitrogen taken up by the crop (total crop N) in addition to the soil mineral nitrogen (SMN) at any particular time. Only the total SNS at harvest was calculated in this study.

Statistical analyses were performed using ANOVAR in the GENSTAT computer software package.

Results

Crop yields

The results for levels of significant differences due to nitrogen and fungicide treatments applied to each the six experiments in the first year of the experiment are shown in Table 5, for the main indicator parameters of crop yields. Table 6 shows the similar set of results for the second year of the experiments.

Yields for the first year wheat varied little between the straw incorporation experiments within each site, being 9.6 , 8.3 and 9.6 t ha^{-1} at Boxworth, Bridgets and Terrington respectively on the incorporated plots, and 9.7, 8.1 and 9.5 t ha^{-1} on those that had straw baled and removed (Figs. 1 & 4). This was expected (as the effect was applied after harvest), but does signify that there were no purely spatial differences between the two experimental areas on each site, and that differences in the second year could more securely be assigned to the treatment of straw. In the second year there was little difference again at Bridgets, where the incorporated area slightly outperformed the baled area by 5.3 to 5.1 t ha^{-1} (Fig. 7). At Boxworth and Terrington however, there was possibly evidence that baling caused higher yields by 3.9 t ha^{-1} compared with 3.3 from the incorporated area at Boxworth, and similarly 2.7 compared with 1.7 t ha^{-1} at Terrington (Fig. 7).

The expected reduction in yield was shown by the second year wheat at Bridgets compared with the first, but the drastic reduction in yields between the first and second years at Boxworth and Terrington was far more than would be expected, and will be discussed in the next section. The yields according to treatment means from each experiment are shown in Tables A1 & A2 for Boxworth, A3 & A4 for Bridgets, and A5 & A6 for Terrington sites. In the first year, the sites show about a 4.5 t ha^{-1} yield increment due to the first 160 kg ha^{-1} N applied (N1 to N2), and then about 0.2 –0.5 t ha^{-1} for the second (N2 to N3), in keeping with yield optimum applications of about 180 kg ha^{-1} for each site (Sylvester-Bradley *et al.,* 1984). Only on the baled plots at Boxworth did the fungicide treatments lead to a significant difference in yields in the first year (Table 5 and Fig 1), where both strobilurin treatments yielded about 0.3-0.4 t ha^{-1} higher than the triazole only programme across all N levels (Table A2). Similar scale differences could be seen at Boxworth incorporated plots and at Terrington, but in neither case proved significant.

In no experiment did the fungicide treatments lead to significant differences in yield for the second year wheat. (Table 6). Nitrogen application treatments displayed a significant residual effect on yield for most of the experiments in the second year (Table 6), where yields could be boosted by 0.2 to 0.8 t ha^{-1} by the highest rate nitrogen at Boxworth and Terrington (Table A1 & A5) on straw incorporated plots, but by 1.6 and 1.3 t ha^{-1} where it had been baled (Table A2 & A6 and Fig. 7). At Bridgets there was a marginal decrease at higher nitrogen treatments if anything (Tables A3 & A4 and Fig 7).

The only other yield forming parameter which showed a significant difference in response to fungicide treatments was the thousand grain weights at Boxworth and Terrington sites in the first year (Tables 5, A7, A8 and A12, and Fig. 2) and Terrington in the second year (Tables 6 and A12). In this case the strobilurin treatments led to larger grain (from about 45 g to 47 – 48 g ; Table A7 & A8) at Boxworth and Terrington (46 g to 48 g; Table A12), but made no discernible difference at Bridgets (all about 40 g; Tables A9 & A10) or on the sites at Terrington (48 & 36 g; Table A11)).

Generally, differences in thousand grain weight between nitrogen treatments were not very significant except at Boxworth in the first year wheat where, higher nitrogen rates tended to produce smaller grain (48 - 49 g for 0 N compared with 45 – 46 g for 320 kg ha^{-1} N; Tables 5, A& & A8). In the second year, grain size tended to be reduced compared with the first, 40 g compared with 46 – 47 g at Boxworth and 33 – 36 g compared with 48 g at Terrington, except at Bridgets where they tended to be slightly higher (42 – 46 g compared with 40 g). Where residual nitrogen from the nitrogen treatments caused a significant effect in the second year (Boxworth incorporated, Bridgets baled and Terrington baled; Table 6) the trend was to smaller grain at higher nitrogen as before (Table A7, A10 & A12).

Both shoot and ear numbers showed no significant response to fungicide treatment in either first or second year wheat (Tables 5 & 6), and showed entirely predictable increase with nitrogen application rates in the first year (shoot numbers not shown; ear numbers given in Tables A13 – A18). In the second year ear numbers continued to show a similar response to residual nitrogen in the baled straw experiments (Tables A6, A14, A16 & A18) as well as the incorporated at Terrington (Table A17), albeit at a reduced level of significance. Ear numbers varied little from the first to second year at Boxworth (514 & 524 to 572 & 512), reduced slightly at Bridgets (from 529 & 503 to 310 & 328), were much reduced at Terrington (455 & 471 to 75 & 74).

Grain numbers also showed no response to fungicide treatments in either the first or second years, but all sites (except Bridgets baled in the second year) showed highly significant differences due to nitrogen levels (Table 5 & 6). At all sites in the first year grain numbers per ear varied from about 31 (Bridgets) to 35 (Boxworth and Terrington) and maintaining those levels at Bridgets (30-36) and Terrington (32 – 35) in the second year, where values tended to be slightly higher in the baled straw experiments. Numbers were however, very much reduced to 9 – 10 at Boxworth in the second year. In all but one case, numbers tended to be higher at higher nitrogen levels (Tables A19, A20, A21, A23 & A24). The exception was at Bridgets in the baled straw experiment where residual nitrogen seemed to reduce numbers, though this was not a significant effect.

Table 5 Significant differences found between treatment means for crop yield component parameters in first year wheat experiments. (*** = P<0.001, ** = P<0.01, * = P<0.05, ns = P>0.05, otherwise P level given)

Parameter	Site	Straw experiment	Nitrogen treatments (N)	Fungicide treatments (F)	N x F Interaction
Shoot No.	Boxworth	Incorporated	***	ns	ns
		Baled	***	ns	ns
	Bridgets	Incorporated	**	ns	ns
		Baled	**	ns	ns
	Terrington	Incorporated	***	ns	ns
		Baled	***	ns	ns
Ear No.	Boxworth	Incorporated	***	ns	ns
		Baled	***	ns	ns
	Bridgets	Incorporated	***	ns	ns
		Baled	**	ns	ns
	Terrington	Incorporated	***	ns	ns
		Baled	***	ns	ns
Grain No.	Boxworth	Incorporated	***	ns	ns
		Baled	***	ns	ns
	Bridgets	Incorporated	**	ns	ns
		Baled	**	ns	ns
	Terrington	Incorporated	***	ns	ns
		Baled	***	ns	ns
1000 grain	Boxworth	Incorporated	***	***	ns
Weight		Baled	***	***	ns
	Bridgets	Incorporated	ns	ns	ns
		Baled	*	ns	ns
	Terrington	Incorporated	ns	ns	ns
		Baled	*	**	ns
Yield	Boxworth	Incorporated	***	ns	ns
		Baled	***	**	ns
	Bridgets	Incorporated	***	ns	ns
		Baled	***	ns	ns
	Terrington	Incorporated	***	ns	ns
		Baled	***	ns	ns

Table 6 Significant differences found between treatment means for crop yield component parameters in second year wheat experiments. (*** = P<0.001, ** = P<0.01, * = P<0.05, ns = P>0.05, otherwise P level given)

Parameter	Site	Straw experiment	Nitrogen treatments (N)	Fungicide treatments (F)	N x F Interaction
Shoot No.	Boxworth	Incorporated	ns	ns	ns
		Baled	**	ns	ns
	Bridgets	Incorporated	*	ns	ns
		Baled	ns	ns	ns
	Terrington	Incorporated	*	ns	ns
		Baled	ns	ns	ns
Ear No.	Boxworth	Incorporated	ns	ns	ns
		Baled	***	ns	ns
	Bridgets	Incorporated	*	ns	ns
		Baled	ns	ns	ns
	Terrington	Incorporated	*	ns	ns
		Baled	*	ns	ns
Grain No.	Boxworth	Incorporated	***	ns	ns
		Baled	***	ns	ns
	Bridgets	Incorporated	**	ns	ns
		Baled	ns	ns	ns
	Terrington	Incorporated	***	ns	ns
		Baled	**	ns	ns
1000 grain	Boxworth	Incorporated	***	ns	ns
Weight		Baled	ns	ns	ns
	Bridgets	Incorporated	P = 0.058	ns	ns
		Baled	*	ns	ns
	Terrington	Incorporated	ns	ns	ns
		Baled	**	ns	ns
Yield	Boxworth	Incorporated	***	ns	ns
		Baled	***	ns	ns
	Bridgets	Incorporated	***	ns	ns
		Baled	ns	ns	ns
	Terrington	Incorporated	***	ns	ns
		Baled	***	ns	ns

Nitrogen dynamics

In only two cases did the fungicide treatments lead to significant differences in any parameters indicative of the general nitrogen dynamics of the soil and crop system, and these were for the nitrogen harvest index (NHI) in the first year at Bridgets where straw was incorporated (Table 7), and soil mineral nitrogen in the spring (SMN) in the second year at Bridgets where straw was baled and removed (Table 8). Three other cases which indicated possibly significant differences in the first year, soil mineral nitrogen at harvest (HMN) at Boxworth (baled) and Terrington (incorporated) and NHI at Terrington (incorporated) (Table 7), cannot be accepted as such because the interaction terms are also significant (Table 7).

For all parameters in the first year, except SMN, the nitrogen treatments proved highly significant sources of variation. This is axiomatic, because they all include an element of applied nitrogen. Where this could legitimately be subtracted, such as a re-working of SNS, the differences were no longer significant. In the second year, no parameters showed significant differences due to nitrogen treatments in either of the experiments at Bridgets.

The parameter which most comprehensively indicates the general nitrogen fertility of the experiments is the total soil nitrogen supply at harvest time. As stated above, this proved highly significant at all sites in the first year (Table 7), but only because of the applied fertiliser nitrogen (Tables B1 – B6), though levels varied greatly between sites from 426 & 412 kg ha^{-1} N at Boxworth, through 348 & 335 kg ha^{-1} at Bridgets to 239 & 218 kg ha^{-1} N at Terrington. These differences were in part due to differences in the inherent mineral nitrogen levels of each site, 156 - 176 kg ha^{-1} at Boxworth (Tables B19 & B20), 130 – 152 kg ha-1 at Bridgets (Tables B21 & B22) and 96 – 109 kg ha-1 at Terrington (Tables B23 & B24). However, SMN showed no differences within each experiment (Tables 7, B19 – B224), and thereby confirmed that any differences apparent in the second year were indeed caused by the applied treatments and not spatial variation.

Of more interest were differences apparent in the second year from residual nitrogen in the soil, where both Boxworth and Terrington recorded differences in total nitrogen supply due to residual nitrogen from the treatments applied in the first year (Table 8). This was not the case at Bridgets where levels were more uniform across treatments (Tables B3 & B4). At Boxworth the first160 kg ha^{-1} N applied in the first year was worth approximately 25 – 30 kg ha^{-1} in the second year, and the second 160 kg ha^{-1} worth an extra 40 kg ha^{-1} N Tables B1 and B2) (Fig. 8). At Terrington these figures proved to only be worth about 15 kg ha^{-1} N or less (Tables B5 & B6 and Fig.8). There was little difference between the experiments where straw was incorporated and those where it was baled and removed, though the latter tended to have the slightly higher SNS in the second year.

In the single case in the first year where fungicide treatments led to significant differences in NHI, Bridgets (incorporated) (Table 7), this was due to a slightly lower NHI for treatment F2 (triazole plus azoxystrobin)(Table B9). There was no hint of this effect at either Boxworth (Table B7) or Terrington (Table B11), or in second year effects for any site. Generally the NHI was lower at Boxworth in the first year (0.6 & 0.64) compared with Bridgets (0.74 and 0.61) and Terrington (0.81 and 0.79), but increased at this site in the second year (to 0.74 and 0.76), whereas it decreased in the second year at Terrington (to 0.64 and 0.68) and remained similar at Bridgets (to 0.76 for both experiments). Nitrogen treatments had no effect on NHI at any site or straw treatment in the second year, and conflicting effects at Bridgets (Table B10) and Terrington (Table B12) in the first year.

A large part of the total SNS of a site is measured by the nitrogen taken up by the crop in the total N offtake (not shown), and most of this is the grain N offtake (Tables B13 to B 118). Both parameters indicated that residual nitrogen effects from the first year caused highly significant differences in the second (Table 8) at Boxworth and Terrington. At Boxworth this could be nearly 40 kg ha^{-1} N from the highest nitrogen application (Tables B13 & B14), but at Terrington amounted to only an extra 10 kg ha-1 N from the same application (Tables B17 & B18). This is indicative of the drastic reduction in grain N offtake at Terrington from 144 and 143 kg ha-1 N mean offtake for the incorporated and baled experiments respectively, to only 16 and 18 kg ha^{-1} N in the second year. A large reduction was also recorded at Bridgets, from 138 & 140 kg ha^{-1} N to 57 and 66 for the incorporated and baled experiments respectively, but smaller decreased at Boxworth (171 & 174 to 119 & 130 kg ha^{-1} N).

Only at the baled straw experiment at Boxworth were any significant residual nitrogen effects from the nitrogen application treatments in the first year, still apparent in the remaining soil nitrogen at harvest (HMN) in the second year (Table 8) (Table B26). This indicates either, that the test crop in the second year was successful in taking up all excess nitrogen differences generated in the first year or that an external event also removed nitrogen from the site to eradicate the differences in HMN left after the first harvest (Table 7) (Tables B25 – B30). The nitrogen treatments left large differences in HMN (Table 7) after the first year harvest, with over 200 kg ha^{-1} N being left as soil mineral nitrogen in the highest N treatment plots at Boxworth and Bridgets to go into the winter (Fig. 5), and were the source of the significant differences in SMN in the second year due to nitrogen treatment at Boxworth and Terrington (Tables 8, B19, B20 and B23)(Fig. 6).

Table 7 Significant differences found between treatment means for nitrogen dynamic parameters in first year wheat experiments. (*** = P<0.001, ** = P<0.01, * = P<0.05, ns = P>0.05, otherwise P level given)

Parameter	Site	Straw experiment	Nitrogen treatments (N)	Fungicide treatments (F)	N x F Interaction
Spring SMN	Boxworth	Incorporated	ns	ns	ns
		Baled	ns	ns	ns
	Bridgets	Incorporated	ns	ns	ns
		Baled	ns	ns	ns
	Terrington	Incorporated	ns	ns	ns
		Baled	ns	ns	ns
Harvest SMN	Boxworth	Incorporated	***	ns	ns
		Baled	***	*	*
	Bridgets	Incorporated	***	ns	ns
		Baled	***	ns	ns
	Terrington	Incorporated	***	ns	*
		Baled	***	ns	ns
Grain N offtake	Boxworth	Incorporated	***	ns	ns
		Baled	***	ns	ns
	Bridgets	Incorporated	***	ns	ns
		Baled	***	ns	ns
	Terrington	Incorporated	***	ns	ns
		Baled	***	ns	ns
Total N offtake	Boxworth	Incorporated	***	ns	ns
		Baled	***	ns	ns
	Bridgets	Incorporated	***	ns	ns
		Baled	***	ns	ns
	Terrington	Incorporated	**	ns	ns
		Baled	***	ns	ns
NHI	Boxworth	Incorporated	**	ns	ns
		Baled	ns	ns	ns
	Bridgets	Incorporated	ns	**	ns
		Baled	**	ns	ns
	Terrington	Incorporated	*	*	*
		Baled	**	ns	ns
Total SNS	Boxworth	Incorporated	***	ns	ns
		Baled	ns	ns	ns
	Bridgets	Incorporated	***	ns	ns
		Baled	***	ns	ns
	Terrington	Incorporated	***	ns	ns
		Baled	***	ns	ns

Table 8 Significant differences found between treatment means for nitrogen dynamic parameters in second year wheat experiments. (*** = P<0.001, ** = P<0.01, * = P<0.05, ns = P>0.05, otherwise P level given)

Parameter	Site	Straw experiment	Nitrogen treatments (N)	Fungicide treatments (F)	N x F Interaction
Spring SMN	Boxworth	Incorporated	**	ns	ns
		Baled	**	ns	ns
	Bridgets	Incorporated	ns	ns	ns
		Baled	ns	*	ns
	Terrington	Incorporated	***	ns	ns
		Baled	ns	ns	ns
Harvest SMN	Boxworth	Incorporated	ns	ns	ns
		Baled	**	ns	ns
	Bridgets	Incorporated	ns	ns	ns
		Baled	ns	ns	ns
	Terrington	Incorporated	ns	ns	ns
		Baled	ns	ns	ns
Grain N offtake	Boxworth	Incorporated	***	ns	ns
		Baled	***	ns	ns
	Bridgets	Incorporated	ns	ns	ns
		Baled	ns	ns	ns
	Terrington	Incorporated	***	ns	ns
		Baled	**	ns	ns
Total N offtake	Boxworth	Incorporated	***	ns	ns
		Baled	***	ns	ns
	Bridgets	Incorporated	ns	ns	ns
		Baled	ns	ns	ns
	Terrington	Incorporated	***	ns	ns
		Baled	**	ns	ns
NHI	Boxworth	Incorporated	ns	ns	ns
		Baled	ns	ns	ns
	Bridgets	Incorporated	ns	ns	ns
		Baled	ns	ns	ns
	Terrington	Incorporated	ns	ns	ns
		Baled	ns	ns	ns
Total SNS	Boxworth	Incorporated	***	ns	ns
		Baled	***	ns	ns
	Bridgets	Incorporated	ns	ns	ns
		Baled	ns	ns	ns
	Terrington	Incorporated	**	ns	ns
		Baled	**	ns	ns

Discussion

There was only slight evidence for the previously reported yield advantage due to the use of strobilurins from the first year results. Yields were enhanced at Boxworth, and possibly at Terrington but at a much lower level of probability. The enhancement effect was of the order of 0.3 - 0.4 t ha^{-1} and seems to have been caused by larger grain rather than increased numbers or ear numbers, but however, was not observed in total or grain N offtake (Fig. 3) unlike the results of Bryson (2000). Furthermore, there was no hint of any carried over effect in the second year wheat at any site, or for any level of nitrogen fertiliser applied in the first year.

It was hypothesised in the introduction that the use of strobilurins may either, leave a reduced residual amount of nitrogen in the soil for following crops (Bryson, 2000), or via increased returns in straw, enhanced levels of re-mobilised nitrogen for a second crop in the following spring. Once again there was no real evidence in these experiments for either differential amounts of nitrogen in the soil in the spring (SMN, Tables B19 - B24), or increased uptake from soil organic sources during the lifetime of a following wheat crop (Total SNS, Tables B25 – B30). Total soil nitrogen supply in the second year indicated no effect due to fungicide treatments in the previous year for any site, and irrespective of the manner in which straw was managed in the first year (Fig. 9).

On the face of it a negative conclusion to the original questions, as to whether there is a carried-over effect of strobilurin use in the nitrogen nutrition of second wheats and whether this needs management, is called for. However, the larger than expected drop in yield at Boxworth and Terrington, was caused by unforeseen extreme weather conditions during the autumn and winter, which may have overcome any marginal treatment effects on soil nitrogen supply. Excessive rainfall during the autumn (Table 9) caused both a prolonged delay in crop establishment at Boxworth (Table 2) which had to be sown late (December) by broadcasting rather than drilling, and crop failure due to water-logging at Terrington. A replacement crop at Terrington could not be established until January in the following year. In both cases, nitrogen uptake by these crops would have been drastically reduced compared to one established in early autumn. Where this had been accomplished, at Bridgets, yields were not quite so dramatically diminished for a second wheat.

Table 9 shows that Boxworth and Terrington experienced rainfall of 158 and 126 mm in excess of the long term means at these sites, which effectively prevented the timely establishment of the second wheat crop. This would also have caused excessive early winter drainage, and thereby leaching of nitrogen mineralised in the autumn. Any such nitrogen would have still been in the soil and labile, not having been taken up by a well established crop. At Bridgets 117 mm of excess rainfall was still experienced, but the shallow nature of the soil overlying deeply fissured chalk, allowed this to drain more effectively, allowing sufficient machinery working days for drilling when the clay soils at Boxworth and Terrington were still impassable. The presence of a crop during this late autumn period would also reduced N loss, because a proportion of the labile soil N would be taken up by the crop (though only of the order of 5 kg ha^{-1} N).

Table 9 Monthly rainfall (mm) figures for late autumn and early winter period of crop establishment in 2000. (40 yr mean monthly rainfall (mm) shown in parentheses for each site).

Early winter period in 2000	Boxworth	Bridgets	Terrington
September	70 (50)	72 (64)	87 (52)
October	116 (49)	114 (79)	95 (50)
November	112 (51)	135 (81)	114 (58)
December	58 (48)	108 (88)	41 (51)

The efficacy of this rainfall at removing nitrogen from the soil can be seen by subtracting the SMN figures for the second year experiments from the HMN figures from the first year (Table 10). This will not of course equate exactly, as small amounts have been taken up by the crop, and larger amounts mineralised from the soil organic nitrogen pool to contribute to the second year SMN, but the values in Table 10 indicate the order of magnitude of nitrogen leaching which took place over the sites during the winter of 2000.

Table 10 Difference in soil mineral nitrogen between harvest after the first year wheat (HMN) and spring (SMN) in the second year wheat (kg ha^{-1} N). Positive values suggest nitrogen leached from the root zone, whereas negative values suggest nitrogen mineralised from soil organic nitrogen sources.

Straw experiment	Nitrogen treatment	Boxworth	Bridgets	Terrington
Incorporated straw	N1	3	40	-30
	N2	8	21	-41
	N3	150	113	23
Baled straw	N1	5	12	-32
	N2	33	9	-41
	N3	112	120	-12

Where large amounts of mineral nitrogen were left in the soil (N3) treatments at Boxworth and Bridgets) over 100 kg ha^{-1} N was leached from the rooting zone of the soil profile. On the shallow soil at Bridgets sizeable amounts could also be leached from lower application rate treatments, whereas at Terrington where large amounts were not left and so a net contribution of mineralised nitrogen from soil organic sources was recorded. Soil nitrogen supply did seem to be less efficient at Terrington (Tables B1 – B6) compared to the other sites, even though similar amounts of nitrogen were taken off as grain in the first year (Tables B13 – B18).

In general, the reduction in yield in the second year wheat at Boxworth and Terrington was slightly more depressed in the plots where straw had been incorporated rather than baled and removed (by about 0.6 – 1.0 t ha^{-1}). This is in keeping with theory that extra, high C:N ratio crop residues in the soil tend to immobilise mineral nitrogen in the soil (Bhogal *et al.,* 1997). A large factor in the reduced yield was smaller grain size across both sites. However, the sites differed in that the main yield determinant at Boxworth was ear number (Tables A13 & A14) with reduced grain numbers per ear (Tables A19 & A20); whereas the reverse was true at Terrington (Tables A17 & A18 and A23 & A24), where grain numbers remain similar across treatments and ear numbers were reduced.

Conclusions

Although there was some evidence for a yield enhancement from the use of strobilurin fungicides in the year of their use, there was no detectable effect on residual soil mineral nitrogen in that year ! Nor was there any detectable effect in the following year after a winter of excessive rainfall. It must be allowed that this excessive rainfall, and the poor crop establishment (and thereby lower early nitrogen uptake), could have masked a minor carry-over effect of reduced nitrogen from the fungicide treatments. However, this would only of been of minor amounts of nitrogen, and so no worthwhile guidelines for specifically managing nitrogen in second wheat after strobilurin use can be recommended in response to the second objective of this series of experiments.

The use of large applications of nitrogen (320 kg ha^{-1}) on wheat, led to the leaching of approximately one third of it during a wet winter, and less than half of this carried over and available to the following crop. The incorporation or removal of straw, did not show a consistent trend of effecting the availability of nitrogen over this period to leaching or uptake by a following crop, but suggested a slight depression of yield of less than 1 ha^{-1}. Neither does the amount of nitrogen applied, seem to have any interactive effect on the yield enhancement by strobilurins, and so the only real recommendation to be indicated by this series of experiments is to avoid over supply of fertiliser nitrogen, beyond the economic optimum application for any particular site.

References

Bhogal A., Young S.D. & Sylvester-Bradley R. 1997. Straw incorporation and immobilisation of spring-applied nitrogen. *Soil Use and Management*, ***13***: 111-116.

Bryson R.J. 2000. The residual effects of strobilurin fungicides on soil nitrogen for the following crop. HGCA Project Report no. 221. Publ. HGCA, London. 18pp.

Hodge C A H, Burton R G O, Corbett W M, Evans R, & Seale R S. 1984. Soils and their use in Eastern England. *Soil Survey of England and Wales, Bulletin No. 13*. Harpenden, UK. 1984. 450pp.

Jarvis M.G., Allen R.H., Fordham S.J., Hazelden J., Moffat A.J. & Sturdy R.G. 1984. Soils and their use in South East England. Soil Survey of England and Wales, Bulletin No. 15. Publ., Soil survey of England and Wales, Harpenden, UK. 405pp.

Jones D.R., & Bryson R.J. 1998. Maximising the benefits for growers from new fungicide chemistry. HGCA Project Report no. 164. Publ. HGCA, London. 31pp.

Sylvester-Bradley R., Dampney P.M.R. & Murray A.W.A. 1984. The response of winter wheat to nitrogen. In, "The nitrogen requirement of cereals," MAFF/ADAS Reference book 385. Publ. HMSO, London. 151-174

Sylvester-Bradley R. 1996. Adjusting N applications according to N applied for the last crop. *Aspects of Applied Biology,**47**, Rotations and cropping systems*: 67-76.

APPENDIX A Crop yield components.

Table A1 *Crop yields (combine)(85% DM) for Incorporated straw experiment at ADAS Boxworth. (S.E.D.;1st year ± 0.16; 2nd year ± 0.15)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	6.6	6.5	6.7	6.6
	N2	10.5	11.2	11.1	10.9
	N3	10.8	11.5	11.4	11.2
	Mean	9.3	9.7	9.8	***9.6***
2nd year wheat	N1	2.8	2.9	2.8	2.8
	N2	3.1	3.0	2.9	3.0
	N3	4.1	4.2	4.2	4.2
	Mean	3.4	3.4	3.3	***3.3***

Table A2 *Crop yields (combine)(85% DM) for Baled straw experiment at ADAS Boxworth. (S.E.D.;1st year ± 0.21; 2nd year ± 0.35)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	6.9	7.3	7.1	7.1
	N2	10.7	11.1	11.2	11.0
	N3	10.7	11.4	11.2	11.1
	Mean	9.5	9.9	9.8	***9.7***
2nd year wheat	N1	3.1	3.4	3.1	3.2
	N2	3.7	3.4	3.6	3.6
	N3	4.8	4.7	4.8	4.8
	Mean	3.9	3.8	3.9	***3.9***

Table A3 *Crop yields (combine)(85% DM) for Incorporated straw experiment at ADAS Bridgets. (S.E.D.;1st year ± 0.15; 2nd year ± 0.13)*

Year of Experiment	**Nitrogen Treatment**	**Fungicide Treatment**			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	5.1	5.2	5.3	5.2
	N2	9.6	9.7	9.8	9.7
	N3	10.0	9.8	10.0	9.9
	Mean	8.3	8.2	8.4	***8.3***
2nd year wheat	N1	5.4	5.4	5.5	5.4
	N2	5.2	5.4	5.2	5.3
	N3	5.1	5.1	5.0	5.1
	Mean	5.2	5.3	5.2	***5.3***

Table A4 *Crop yields (combine)(85% DM) for Baled straw experiment at ADAS Bridgets. (S.E.D.;1st year ± 0.18; 2nd year ± 0.22)*

Year of Experiment	**Nitrogen Treatment**	**Fungicide Treatment**			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	5.1	5.0	5.1	5.1
	N2	9.5	9.3	9.6	9.5
	N3	9.7	9.8	9.9	9.8
	Mean	8.1	8.1	8.2	***8.1***
2nd year wheat	N1	5.1	5.2	5.3	5.2
	N2	5.2	5.0	4.9	5.0
	N3	5.0	4.8	5.1	5.0
	Mean	5.1	5.0	5.1	***5.1***

Table A5 *Crop yields (combine)(85% DM) for Incorporated straw experiment at ADAS Terrington. (S.E.D.;1st year ± 0.36; 2nd year ± 0.24)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			Mean
		F1	**F2**	**F3**	
1st year wheat	N1	6.1	6.1	5.9	6.0
	N2	10.9	11.4	11.4	11.2
	N3	11.1	11.9	12.1	11.7
	Mean	9.4	9.8	9.8	***9.6***
2nd year wheat	N1	1.5	1.4	1.3	1.4
	N2	1.5	1.7	1.3	1.5
	N3	2.3	2.2	2.2	2.2
	Mean	1.7	1.8	1.6	***1.7***

Table A6 *Crop yields (combine)(85% DM) for Baled straw experiment at ADAS Terrington. (S.E.D.;1st year ± 0.60; 2nd year ± 0.40)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			Mean
		F1	**F2**	**F3**	
1st year wheat	N1	6.3	6.2	6.7	6.4
	N2	11.1	10.5	10.8	10.8
	N3	10.4	11.2	12.1	11.3
	Mean	9.3	9.3	9.9	***9.5***
2nd year wheat	N1	2.2	2.2	2.0	2.2
	N2	3.1	2.2	3.6	2.5
	N3	3.7	3.6	3.3	3.5
	Mean	3.0	2.7	2.5	***2.7***

Table A7 *Thousand grain weight (g) for Incorporated straw experiment at ADAS Boxworth. (S.E.D.;1st year ± 0.36; 2nd year ± 0.99)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	47.0	47.6	48.6	47.7
	N2	45.8	47.6	46.9	46.8
	N3	43.4	45.2	45.6	44.7
	Mean	45.4	46.8	47.0	***46.4***
2nd year wheat	N1	39.6	40.1	40.3	40.0
	N2	41.0	41.8	40.6	41.2
	N3	37.8	38.25	38.6	38.2
	Mean	39.5	40.1	39.9	***39.8***

Table A8 *Thousand grain weight (g) for Baled straw experiment at ADAS Boxworth. (S.E.D.;1st year ± 0.36; 2nd year ± 1.13)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	48.2	50.0	49.6	49.3
	N2	44.4	47.4	47.6	46.5
	N3	44.4	46.7	45.8	45.6
	Mean	45.7	48.0	47.7	***47.1***
2nd year wheat	N1	40.9	40.0	40.7	40.6
	N2	41.7	41.8	40.9	41.5
	N3	39.7	40.5	40.0	40.0
	Mean	40.8	40.8	40.5	***40.7***

Table A9 *Thousand grain weight (g) for Incorporated straw experiment at ADAS Bridgets. (S.E.D.;1st year $\pm$ 0.55; 2nd year $\pm$ 1.64)*

Year of Experiment	**Nitrogen Treatment**	**Fungicide Treatment**			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	40.6	40.6	40.3	40.5
	N2	40.7	40.2	40.0	40.3
	N3	39.9	39.8	40.6	40.1
	Mean	40.4	40.2	40.3	***40.3***
2nd year wheat	N1	45.3	48.7	47.7	47.2
	N2	44.3	45.1	45.1	44.9
	N3	45.5	45.0	46.6	45.7
	Mean	45.0	46.3	46.5	***45.9***

Table A10 *Thousand grain weight (g) for Baled straw experiment at ADAS Bridgets. (S.E.D.;1st year $\pm$ 0.55; 2nd year $\pm$ 0.62)*

Year of Experiment	**Nitrogen Treatment**	**Fungicide Treatment**			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	40.6	39.9	40.5	40.3
	N2	40.9	40.4	41.8	41.0
	N3	40.3	40.3	40.4	40.3
	Mean	40.6	40.2	40.9	***40.5***
2nd year wheat	N1	42.2	42.7	42.2	42.4
	N2	41.5	41.7	41.5	41.6
	N3	42.0	41.4	41.5	41.6
	Mean	41.9	41.9	41.7	***41.9***

Table A11 *Thousand grain weight (g) for Incorporated straw experiment at ADAS Terrington. (S.E.D.;1st year ± 1.12; 2nd year ± 1.85)*

Year of Experiment	**Nitrogen Treatment**	**Fungicide Treatment**			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	47.6	48.2	49.0	48.3
	N2	48.6	48.5	49.3	48.8
	N3	47.3	50.2	47.9	48.4
	Mean	47.8	48.9	48.7	***48.5***
2nd year wheat	N1	31.6	31.7	33.5	32.3
	N2	33.8	32.5	32.1	32.8
	N3	32.8	33.1	32.3	32.7
	Mean	32.7	32.5	32.6	***32.6***

Table A12 *Thousand grain weight (g) for Baled straw experiment at ADAS Terrington. (S.E.D.;1st year ± 1.17; 2nd year ± 1.50)*

Year of Experiment	**Nitrogen Treatment**	**Fungicide Treatment**			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	47.8	47.5	49.1	48.1
	N2	46.3	49.3	48.3	48.0
	N3	44.2	46.4	48.3	46.3
	Mean	46.13	47.75	48.58	***47.5***
2nd year wheat	N1	36.7	37.2	36.9	36.9
	N2	36.2	37.7	36.3	36.7
	N3	34.8	33.2	34.7	34.3
	Mean	35.9	36.0	36.0	***36.0***

Table A13 *Ear numbers (m^{-2}) for Incorporated straw experiment at ADAS Boxworth. (S.E.D.; 1st year $\pm$ 16.4; 2nd year $\pm$ 104.1)*

Year of Experiment	**Nitrogen Treatment**	**Fungicide Treatment**			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	394	415	436	415
	N2	531	522	556	536
	N3	594	592	586	591
	Mean	506	510	526	***514***
2nd year wheat	N1	619	474	512	535
	N2	459	504	758	574
	N3	645	545	626	606
	Mean	575	508	633	***572***

Table A14 *Ear numbers (m^{-2}) (85% DM) for Baled straw experiment at ADAS Boxworth. (S.E.D.; 1st year $\pm$ 17.2; 2nd year $\pm$ 45.1)*

Year of Experiment	**Nitrogen Treatment**	**Fungicide Treatment**			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	430	418	433	427
	N2	528	580	548	552
	N3	591	585	606	594
	Mean	516	528	529	***524***
2nd year wheat	N1	469	428	489	462
	N2	479	513	510	501
	N3	567	601	552	574
	Mean	505	515	517	***512***

Table A15 *Ear numbers (m^{-2}) for Incorporated straw experiment at ADAS Bridgets. (S.E.D.;1st year ± 34.1; 2nd year ± 22.1)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment F1	F2	F3	Mean
1st year wheat	N1	377	377	366	373
	N2	603	586	554	581
	N3	615	671	610	632
	Mean	532	545	510	***529***
2nd year wheat	N1	309	304	302	305
	N2	296	299	279	292
	N3	331	335	331	332
	Mean	312	313	304	***310***

Table A16 *Ear numbers (m^{-2}) for Baled straw experiment at ADAS Bridgets. (S.E.D.;1st year ± 48.9; 2nd year ± 25.6)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment F1	F2	F3	Mean
1st year wheat	N1	287	379	368	344
	N2	599	541	596	579
	N3	578	584	598	587
	Mean	488	501	521	***503***
2nd year wheat	N1	328	299	323	317
	N2	305	339	363	336
	N3	315	343	334	331
	Mean	316	327	340	***328***

Table A17 *Ear numbers (m^{-2}) for Incorporated straw experiment at ADAS Terrington. (S.E.D.; 1st year ± 33.7; 2nd year ± 12.6)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	327	320	328	325
	N2	536	510	478	508
	N3	517	511	568	532
	Mean	460	447	458	***455***
2nd year wheat	N1	68	63	69	67
	N2	79	68	65	71
	N3	88	87	82	86
	Mean	78	73	72	***75***

Table A18 *Ear numbers (m^{-2}) for Baled straw experiment at ADAS Terrington. (S.E.D.; 1st year ± 38.2; 2nd year ± 14.4)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	348	332	380	353
	N2	557	477	510	515
	N3	547	563	523	544
	Mean	484	457	471	***471***
2nd year wheat	N1	69	79	56	68
	N2	73	59	67	67
	N3	100	76	83	86
	Mean	81	72	69	***74***

Table A19 Grain number per ear for Incorporated straw experiment at ADAS Boxworth. (S.E.D.;1st year ± 0.56; 2nd year ± 2.20)

Year of Experiment	**Nitrogen Treatment**	**Fungicide Treatment**			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	29.5	29.3	29.8	29.5
	N2	39.1	39.3	38.3	38.9
	N3	38.2	37.8	37.3	38.1
	Mean	35.6	35.5	35.1	***35.5***
2nd year wheat	N1	8.8	6.5	7.7	7.7
	N2	6.9	7.9	11.4	8.7
	N3	15.1	12.0	14.3	13.8
	Mean	10.3	8.8	11.1	***10.1***

Table A20 Grain number per ear for Baled straw experiment at ADAS Boxworth. (S.E.D.;1st year ± 1.03; 2nd year ± 1.76)

Year of Experiment	**Nitrogen Treatment**	**Fungicide Treatment**			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	29.4	28.7	28.6	28.9
	N2	38.8	36.9	37.1	37.6
	N3	36.9	35.4	35.0	35.8
	Mean	35.0	33.7	33.6	***34.1***
2nd year wheat	N1	7.1	6.2	7.1	6.8
	N2	8.0	8.9	8.7	8.5
	N3	11.7	14.0	10.9	12.2
	Mean	8.9	9.7	8.9	***9.2***

Table A21 *Grain number per ear for Incorporated straw experiment at ADAS Bridgets. (S.E.D.;1st year ± 2.19; 2nd year ± 2.25)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	29.8	32.3	32.0	31.3
	N2	28.5	32.3	30.3	30.3
	N3	28.3	35.8	32.0	32.0
	Mean	28.8	33.4	31.4	***31.2***
2nd year wheat	N1	32.4	30.8	28.4	30.5
	N2	35.1	31.1	33.9	33.3
	N3	28.6	28.4	27.5	28.1
	Mean	32.0	30.1	29.9	***30.6***

Table A22 *Grain number per ear for Baled straw experiment at ADAS Bridgets. (S.E.D.;1st year ± 2.99; 2nd year ± 2.62)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	30.0	26.7	26.7	27.8
	N2	33.2	36.2	30.2	33.2
	N3	34.0	34.0	32.5	33.5
	Mean	32.4	32.3	29.8	***31.5***
2nd year wheat	N1	35.4	36.9	39.6	37.3
	N2	38.0	35.6	33.8	35.8
	N3	36.2	35.3	33.2	34.9
	Mean	36.5	35.9	35.5	***36.0***

Table A23 *Grain number per ear for Incorporated straw experiment at ADAS Terrington. (S.E.D.;1st year ± 1.73; 2nd year ± 3.74)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	33.4	32.2	31.5	32.4
	N2	36.6	37.1	39.1	37.6
	N3	36.8	36.1	37.1	36.7
	Mean	35.6	35.1	35.9	***35.6***
2nd year wheat	N1	29.3	26.6	24.9	26.9
	N2	29.2	37.2	29.6	32.0
	N3	36.8	38.3	35.0	36.7
	Mean	31.8	34.0	29.9	***31.9***

Table A24 *Grain number per ear for Baled straw experiment at ADAS Terrington. (S.E.D.;1st year ± 1.82; 2nd year ± 5.47)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	27.7	29.2	31.0	29.3
	N2	36.2	36.6	37.6	36.8
	N3	34.5	35.0	36.9	35.4
	Mean	32.8	33.5	35.1	***33.8***
2nd year wheat	N1	31.6	27.8	32.3	30.6
	N2	40.0	29.1	29.0	32.7
	N3	44.4	39.2	43.6	42.4
	Mean	38.7	32.0	35.0	***35.2***

APPENDIX B Nitrogen dynamics parameters.

Table B1 *Total soil nitrogen supply (Total SNS) (kg ha^{-1} N) for Incorporated straw experiment at ADAS Boxworth. (S.E.D.; 1st year ± 34.65; 2nd year ± 21.20)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	217.8	244.2	253.4	238.4
	N2	405.5	403.2	425.7	411.5
	N3	661.1	594.4	631.9	629.1
	Mean	428.1	413.9	437.0	***426.3***
2nd year wheat	N1	205.0	211.1	218.2	211.5
	N2	224.3	265.0	237.1	242.1
	N3	286.7	281.1	298.3	288.7
	Mean	238.7	252.4	251.2	***247.4***

Table B2 *Total soil nitrogen supply (Total SNS) (kg ha^{-1} N) for Baled straw experiment at ADAS Boxworth. (S.E.D.; 1st year ±21.38; 2nd year ± 21.73)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	255.9	246.6	238.4	247.0
	N2	396.3	425.0	415.4	412.2
	N3	576.8	608.9	548.0	577.9
	Mean	409.7	426.8	400.6	***412.4***
2nd year wheat	N1	228.3	212.5	219.1	220.0
	N2	263.0	251.8	262.0	258.9
	N3	280.6	319.3	281.2	293.7
	Mean	257.3	261.2	254.1	***257.5***

Table B3 *Total soil nitrogen supply (Total SNS) (kg ha^{-1} N) for Incorporated straw experiment at ADAS Bridgets. (S.E.D.; 1^{st} year ± 24.24; 2^{nd} year ± 8.26)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1^{st} year wheat	N1	233.4	244.8	222.7	233.6
	N2	344.4	345.8	343.3	344.5
	N3	500.7	456.5	448.3	468.5
	Mean	359.5	349.0	338.1	***348.9***
2^{nd} year wheat	N1	173.2	172.7	162.5	169.4
	N2	164.9	159.5	169.7	164.7
	N3	173.4	164.6	172.5	170.2
	Mean	170.5	165.6	168.2	***168.1***

Table B4 *Total soil nitrogen supply (Total SNS) (kg ha^{-1} N) for Baled straw experiment at ADAS Bridgets. (S.E.D.; 1^{st} year ± 23.39; 2^{nd} year ± 14.34)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1^{st} year wheat	N1	208.6	225.6	200.3	211.5
	N2	344.0	315.3	320.2	326.5
	N3	458.1	473.5	473.2	468.3
	Mean	336.9	338.1	331.3	***335.4***
2^{nd} year wheat	N1	187.8	180.5	182.1	183.5
	N2	192.9	206.3	175.9	191.7
	N3	183.1	189.2	173.3	181.8
	Mean	187.9	192.0	177.1	***185.7***

Table B5 *Total soil nitrogen supply (Total SNS) (kg ha^{-1} N) for Incorporated straw experiment at ADAS Terrington. (S.E.D.;1st year ± 36.73; 2nd year ± 13.98)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	116.4	112.6	112.6	113.9
	N2	238.5	242.8	235.4	238.9
	N3	441.1	328.8	320.2	363.4
	Mean	265.3	228.1	222.7	***238.7***
2nd year wheat	N1	68.2	68.7	58.8	65.2
	N2	87.4	76.7	73.4	79.2
	N3	103.8	95.2	89.5	96.2
	Mean	86.5	80.2	73.9	***80.2***

Table B6 *Total soil nitrogen supply (Total SNS) (kg ha^{-1} N) for Baled straw experiment at ADAS Terrington. (S.E.D.;1st year ± 19.77; 2nd year ± 9.98)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	105.3	103.3	112.3	107.0
	N2	237.2	227.3	251.5	238.6
	N3	311.5	316.5	293.9	307.3
	Mean	218.0	215.7	21.9.2	***217.6***
2nd year wheat	N1	81.1	77.8	70.8	76.5
	N2	90.2	72.7	68.1	77.0
	N3	100.1	89.4	93.1	94.2
	Mean	90.4	80.0	77.3	***82.6***

Table B7 *Nitrogen Harvest Index (NHI) for Incorporated straw experiment at ADAS Boxworth. (S.E.D.;1st year ± 0.017; 2nd year ± 0.013)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	0.62	0.59	0.61	0.60
	N2	0.60	0.61	0.61	0.61
	N3	0.57	0.58	0.60	0.58
	Mean	0.60	0.59	0.60	***0.60***
2nd year wheat	N1	0.74	0.73	0.75	0.74
	N2	0.75	0.74	0.72	0.74
	N3	0.75	0.73	0.73	0.74
	Mean	0.75	0.73	0.73	***0.74***

Table B8 *Nitrogen Harvest Index (NHI) for Baled straw experiment at ADAS Boxworth. (S.E.D.;1st year ± 0.030; 2nd year ± 0.024)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	0.62	0.61	0.66	0.63
	N2	0.65	0.67	0.66	0.66
	N3	0.60	0.64	0.65	0.63
	Mean	0.62	0.64	0.66	***0.64***
2nd year wheat	N1	0.77	0.74	0.79	0.77
	N2	0.78	0.76	0.75	0.76
	N3	0.75	0.75	0.75	0.75
	Mean	0.76	0.75	0.76	***0.76***

Table B9 *Nitrogen Harvest Index (NHI) for Incorporated straw experiment at ADAS Bridgets. (S.E.D.;1st year ± 0.026; 2nd year ± 0.017)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	0.76	0.69	0.77	0.74
	N2	0.75	0.73	0.78	0.75
	N3	0.73	0.72	0.73	0.73
	Mean	0.75	0.71	0.76	***0.74***
2nd year wheat	N1	0.77	0.77	0.76	0.77
	N2	0.76	0.76	0.75	0.76
	N3	0.75	0.75	0.77	0.76
	Mean	0.76	0.76	0.76	***0.76***

Table B10 *Nitrogen Harvest Index (NHI) for Baled straw experiment at ADAS Bridgets. (S.E.D.;1st year ± 0.019; 2nd year ± 0.017)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	0.64	0.64	0.61	0.63
	N2	0.60	0.62	0.60	0.61
	N3	0.58	0.59	0.57	0.58
	Mean	0.61	0.62	0.59	***0.61***
2nd year wheat	N1	0.77	0.75	0.77	0.76
	N2	0.77	0.75	0.75	0.76
	N3	0.76	0.76	0.77	0.76
	Mean	0.76	0.75	0.76	***0.76***

Table B11 *Nitrogen Harvest Index (NHI) for Incorporated straw experiment at ADAS Terrington. (S.E.D.;1st year ± 0.019; 2nd year ± 0.040)*

Year of Experiment	**Nitrogen Treatment**	**Fungicide Treatment**			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	0.81	0.79	0.81	0.80
	N2	0.80	0.85	0.83	0.83
	N3	0.76	0.84	0.81	0.80
	Mean	0.79	0.83	0.81	***0.81***
2nd year wheat	N1	0.62	0.62	0.64	0.63
	N2	0.65	0.64	0.64	0.64
	N3	0.67	0.66	0.66	0.66
	Mean	0.65	0.64	0.65	***0.64***

Table B12 *Nitrogen Harvest Index (NHI) for Baled straw experiment at ADAS Terrington. (S.E.D.;1st year ± 0.021; 2nd year ± 0.028)*

Year of Experiment	**Nitrogen Treatment**	**Fungicide Treatment**			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	0.78	0.80	0.79	0.79
	N2	0.81	0.83	0.82	0.82
	N3	0.78	0.75	0.79	0.77
	Mean	0.79	0.80	0.80	***0.79***
2nd year wheat	N1	0.68	0.68	0.70	0.69
	N2	0.71	0.67	0.69	0.69
	N3	0.68	0.64	0.69	0.67
	Mean	0.69	0.67	0.69	***0.68***

Table B13 *Grain N offtake (kg ha^{-1}) for Incorporated straw experiment at ADAS Boxworth. (S.E.D.; 1st year $\pm$ 10.71; 2nd year $\pm$ 10.94)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	91.0	95.8	102.3	96.4
	N2	190.5	196.8	202.7	196.7
	N3	222.5	217.8	220.8	220.4
	Mean	168.0	170.2	175.2	***171.2***
2nd year wheat	N1	98.5	98.8	105.9	101.0
	N2	103.9	112.7	106.2	107.6
	N3	153.8	142.0	148.8	148.2
	Mean	118.7	117.8	120.3	***118.9***

Table B14 *Grain N offtake (kg ha^{-1}) for Baled straw experiment at ADAS Boxworth. (S.E.D.; 1st year $\pm$ 8.87; 2nd year $\pm$ 17.23)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	104.7	96.9	100.7	100.7
	N2	190.0	212.0	199.9	200.6
	N3	220.5	220.9	222.7	221.4
	Mean	171.7	176.6	174.4	***174.2***
2nd year wheat	N1	109.7	102.6	110.2	107.5
	N2	125.1	123.2	134.8	127.7
	N3	149.5	171.9	145.0	155.4
	Mean	128.1	132.6	130.0	***130.2***

Table B15 *Grain N offtake (kg ha^{-1}) for Incorporated straw experiment at ADAS Bridgets. (S.E.D.;1st year ± 7.26; 2nd year ± 3.74)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	72.2	69.5	66.5	69.4
	N2	166.5	161.8	165.3	164.5
	N3	178.5	183.3	178.8	180.2
	Mean	139.1	138.2	136.9	***138.0***
2nd year wheat	N1	56.0	58.4	58.6	57.4
	N2	55.6	55.3	58.5	56.4
	N3	58.4	52.8	59.9	57.0
	Mean	56.6	55.5	59.0	***56.9***

Table B16 *Grain N offtake (kg ha^{-1}) for Baled straw experiment at ADAS Bridgets. (S.E.D.;1st year ± 12.4; 2nd year ± 7.5)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	63.6	72.9	71.0	69.2
	N2	176.3	164.8	162.3	167.8
	N3	183.4	182.4	183.5	183.1
	Mean	141.1	140.0	138.9	***140.0***
2nd year wheat	N1	64.5	60.7	70.9	65.4
	N2	69.8	63.0	66.5	66.4
	N3	63.8	66.6	68.3	66.3
	Mean	66.1	63.4	68.6	***66.0***

Table B17 *Grain N offtake (kg ha^{-1}) for Incorporated straw experiment at ADAS Terrington. (S.E.D.;1st year $\pm$ 16.43; 2nd year $\pm$ 3.56)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	67.8	62.5	63.1	64.5
	N2	162.8	173.3	169.6	168.6
	N3	189.4	193.4	211.4	198.1
	Mean	140.0	143.1	148.0	***143.7***
2nd year wheat	N1	12.5	11.2	11.4	11.7
	N2	14.8	16.1	12.3	14.4
	N3	22.5	23.8	19.0	21.8
	Mean	16.6	17.0	14.3	***16.0***

Table B18 *Grain N offtake (kg ha^{-1}) for Baled straw experiment at ADAS Terrington. (S.E.D.;1st year $\pm$ 10.40; 2nd year $\pm$ 5.71)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	62.9	66.6	71.2	66.9
	N2	163.2	158.8	180.1	168.4
	N3	186.1	197.7	199.5	194.4
	Mean	137.4	141.1	151.3	***143.2***
2nd year wheat	N1	14.8	15.4	12.7	14.3
	N2	20.7	12.0	12.9	15.2
	N3	31.4	19.7	26.5	25.9
	Mean	22.3	15.7	17.3	***18.5***

Table B19 *Soil mineral nitrogen in spring (SMN) (kg ha^{-1}) for Incorporated straw experiment at ADAS Boxworth. (S.E.D.;1st year ± 20.8; 2nd year ± 11.8)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	180	185	170	177
	N2	175	160	177	171
	N3	179	162	200	180
	Mean	178	169	182	***176***
2nd year wheat	N1	76	71	81	76
	N2	83	79	79	80
	N3	108	104	84	99
	Mean	89	85	82	***85***

Table B20 *Soil mineral nitrogen in spring (SMN) (kg ha^{-1}) for Baled straw experiment at ADAS Boxworth. (S.E.D.;1st year ± 17.8; 2nd year ± 22.7)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	153	151	164	156
	N2	170	166	143	160
	N3	153	164	142	153
	Mean	159	160	150	***156***
2nd year wheat	N1	81	91	72	81
	N2	70	73	79	74
	N3	86	150	100	112
	Mean	79	105	84	***89***

Table B21 *Soil mineral nitrogen in spring (SMN) (kg ha^{-1}) for Incorporated straw experiment at ADAS Bridgets. (S.E.D.;1st year $\pm$ 12.1; 2nd year $\pm$ 12.5)*

Year of Experiment	**Nitrogen Treatment**	**Fungicide Treatment**			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	147	153	144	148
	N2	152	146	165	154
	N3	156	148	160	155
	Mean	152	149	156	***152***
2nd year wheat	N1	94	106	100	100
	N2	104	111	110	108
	N3	103	115	101	107
	Mean	100	110	104	***105***

Table B22 *Soil mineral nitrogen in spring (SMN) (kg ha^{-1}) for Baled straw experiment at ADAS Bridgets. (S.E.D.;1st year $\pm$ 18.3; 2nd year $\pm$ 19.9)*

Year of Experiment	**Nitrogen Treatment**	**Fungicide Treatment**			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	143	132	123	132
	N2	116	124	118	119
	N3	126	161	130	139
	Mean	128	139	124	***130***
2nd year wheat	N1	143	103	102	116
	N2	130	93	97	107
	N3	104	96	116	105
	Mean	126	97	105	***109***

Table B23 *Soil mineral nitrogen in spring (SMN) (kg ha^{-1}) for Incorporated straw experiment at ADAS Terrington. (S.E.D.;1st year $\pm$ 16.4; 2nd year $\pm$ 14.0)*

Year of Experiment	**Nitrogen Treatment**	**Fungicide Treatment**			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	105	103	102	103
	N2	87	92	98	92
	N3	90	86	101	93
	Mean	94	94	101	***96***
2nd year wheat	N1	67	68	58	64
	N2	85	75	71	77
	N3	101	92	86	93
	Mean	84	78	72	***78***

Table B24 *Soil mineral nitrogen in spring (SMN) (kg ha^{-1}) for Baled straw experiment at ADAS Terrington. (S.E.D.;1st year $\pm$ 13.1; 2nd year $\pm$ 15.5)*

Year of Experiment	**Nitrogen Treatment**	**Fungicide Treatment**			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	107	101	115	108
	N2	117	105	104	109
	N3	117	99	112	109
	Mean	114	102	110	***109***
2nd year wheat	N1	63	47	50	54
	N2	56	96	68	73
	N3	81	64	55	67
	Mean	67	69	58	***65***

Table B25 *Soil mineral nitrogen after harvest (HMN) (kg ha^{-1}) for Incorporated straw experiment at ADAS Boxworth. (S.E.D.; 1st year ± 24.8; 2nd year ± 18.0)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	72	81	85	79
	N2	88	82	94	88
	N3	272	215	261	249
	Mean	144	126	147	***139***
2nd year wheat	N1	72	76	77	75
	N2	87	111	90	96
	N3	82	88	95	88
	Mean	80	92	87	***86***

Table B26 *Soil mineral nitrogen after harvest (HMN) (kg ha^{-1}) for Baled straw experiment at ADAS Boxworth. (S.E.D.; 1st year ± 15.0; 2nd year ± 7.7)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	86	88	85	86
	N2	102	107	112	107
	N3	207	263	201	224
	Mean	132	153	133	***139***
2nd year wheat	N1	86	74	78	79
	N2	101	89	82	91
	N3	82	91	89	87
	Mean	90	85	83	***86***

Table B27 *Soil mineral nitrogen after harvest (HMN) (kg ha^{-1}) for Incorporated straw experiment at ADAS Bridgets (S.E.D.;1st year $\pm$ 18.9; 2nd year $\pm$ 7.7)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	139	143	136	140
	N2	123	133	131	129
	N3	257	200	203	220
	Mean	173	159	157	***163***
2nd year wheat	N1	97	95	93	95
	N2	85	87	94	89
	N3	96	89	99	95
	Mean	93	90	96	***93***

Table B28 *Soil mineral nitrogen after harvest (HMN) (kg ha^{-1}) for Baled straw experiment at ADAS Bridgets (S.E.D.;1st year $\pm$ 13.0; 2nd year $\pm$ 14.4)*

Year of Experiment	Nitrogen Treatment	Fungicide Treatment			
		F1	F2	F3	Mean
1st year wheat	N1	130	134	120	128
	N2	125	107	116	116
	N3	219	234	224	225
	Mean	158	158	153	***156***
2nd year wheat	N1	104	100	90	98
	N2	114	122	87	108
	N3	99	102	99	100
	Mean	106	108	92	***102***

Table B29 Soil mineral nitrogen after harvest (HMN) (kg ha^{-1}) for Incorporated straw experiment at ADAS Terrington. (S.E.D.;1st year $\pm$ 33.0; 2nd year $\pm$ 5.1)

Year of Experiment	**Nitrogen Treatment**	**Fungicide Treatment**			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	33	34	34	34
	N2	37	40	31	36
	N3	192	97	58	116
	Mean	87	57	41	***62***
2nd year wheat	N1	55	51	56	54
	N2	56	55	55	55
	N3	58	54	59	57
	Mean	56	53	57	***55***

Table B30 Soil mineral nitrogen after harvest (HMN) (kg ha^{-1}) for Baled straw experiment at ADAS Terrington. (S.E.D.;1st year $\pm$ 9.7; 2nd year $\pm$ 6.3)

Year of Experiment	**Nitrogen Treatment**	**Fungicide Treatment**			
		F1	**F2**	**F3**	**Mean**
1st year wheat	N1	24	20	23	22
	N2	35	34	27	32
	N3	71	53	42	55
	Mean	43	36	30	***36***
2nd year wheat	N1	54	51	52	52
	N2	56	50	57	54
	N3	59	51	53	54
	Mean	56	51	54	***53***