HGCA

PROJECT REPORT No. 221

THE RESIDUAL EFFECTS OF STROBILURIN FUNGICIDES ON SOIL NITROGEN FOR THE FOLLOWING CROP

APRIL 2000

Price £3.00

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THE RESIDUAL EFFECTS OF STROBILURIN FUNGICIDES ON SOIL NITROGEN FOR THE FOLLOWING CROP

by

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This is the final report of a one year project which started in December 1998. The work was funded by a grant of £9,980 from HGCA (project no. 2108).

Abstract

This project asks the question " Do strobilurin fungicides increase the depletion of soil nitrogen, and hence increase the need for nitrogen on the following crop ?"

Season one (1998):-

- Increasing inputs of nitrogen increased disease severity in untreated crops,

- All fungicide treatments gave good disease control with yield responses of between
2.8 - 7.7 t/ha depending on nitrogen input,

- The application of two strobilurin fungicide programmes gave a maximum yield response of 1.4 t/ha over the triazole treatment,

- Crop nitrogen offtake increased in the two strobilurin programmes by 10.91 - 39.38 kg N/ha compared to the triazole programme, depending on nitrogen input.

The Following Season (1999):-

- Nitrogen inputs and fungicide treatments in the 1998 experiment resulted in differences in Soil Nitrogen Supply (SNS) to the 1999 crop,

- SNS for the 1999 crop was greatest following low yields in the 1998 crop due to a high level of disease, which resulted in low nitrogen offtake,

- SNS following treatment with the two strobilurin programmes was generally lower than when crops were treated with the triazole programme,

- Yield, specific weight and grain nitrogen were significantly reduced in the Amistar + Opus treatment compared to the triazole treatment.

- Yield loss of up to £100/ha (grain @ £60/t) occurred following the application of a strobilurin programme to the previous years crop.

Conclusions:-

- Strobilurins generally increase yield and hence nitrogen offtake,

- As a consequence, SNS may be reduced for the following crop,

- Differences in SNS are likely to vary with soil type and season,

- Continued use of strobilurins with no adjustment in nitrogen use may affect future yields and grain quality.

- Guidelines need to be established for appropriate nitrogen management following the use of strobilurin fungicides.

Summary.

This project was set up in order to address the question " Do strobilurin fungicides increase the depletion of soil nitrogen and hence increase the need for nitrogen on the following crop ?".

Since 1997, the strobilurin fungicides azoxystrobin (Amistar - Zeneca) and kresoxim methyl (in mixture as Landmark, Mantra or Ensign - BASF) have been widely used in the agricultural industry for both their disease control, and their claimed yield enhancing properties. In some cases, strobilurins have increased leaf life compared with triazole fungicide programmes (Jones & Bryson, 1998). This effect is not due to disease control alone, which is generally comparable between programmes, but appears to result from increased nitrogen uptake and delayed senescence (Bryson *et al.*, 1998).

In 1998, ADAS funded work to augment the HGCA Crop Intelligence project (HGCA Project No. 0023/1/95) to examine the interaction between nitrogen input and the use of strobilurin fungicides on winter wheat, in comparison with an untreated control and a traditional triazole programme. Nitrogen was applied at a range of inputs with 0, 80, 160, 240 and 320 kg N/ha applied to the yellow rust susceptible variety Brigadier. Four fungicide treatments were compared at each of these nitrogen levels with untreated, Opus, Landmark and Amistar + Opus applications. All treatments were applied as a three spray programme at GS31/32, 33 and 39.

All fungicide treatments gave good disease control resulting in yield responses of 2.80 - 7.71 t/ha. Despite all fungicide treatments giving a similar level of disease control, the use of the two strobilurin programmes gave an increase in yield response over the two triazole programmes with maximum responses of 1.40 (1998) t/ha (Figure 1).

Further crop analysis showed that crop nitrogen offtake increased in the two strobilurin programmes by between 10.91 and 39.38 kg N/ha (1998) when compared with the Opus programmes, at 0, 160 and 320 kg N/ha (Figure 2). The data from this experiment suggested that the use of strobilurin fungicides could potentially result in decreased nitrogen residues in the soil in the following autumn, which in turn would have implications for nitrogen applications for the following seasons crop.

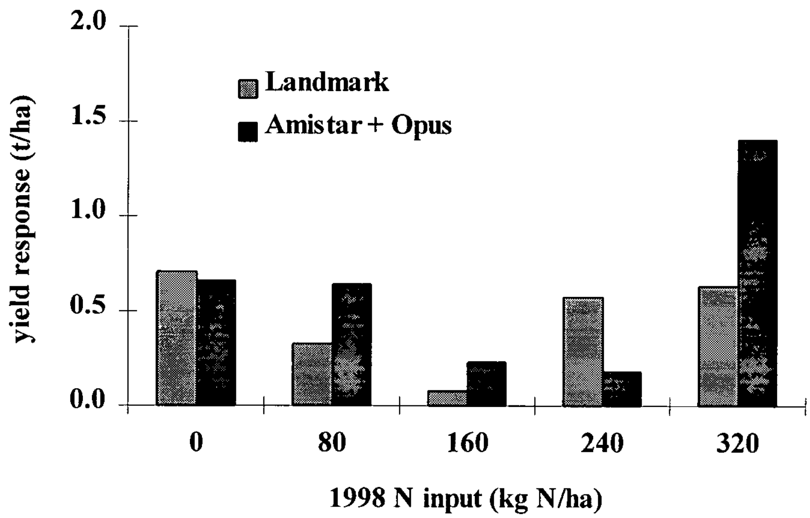

Figure. 1. Yield response (t/ha) following treatment with Landmark and Amistar + Opus in 1998 in comparison with an Opus programme at five levels of nitrogen input.

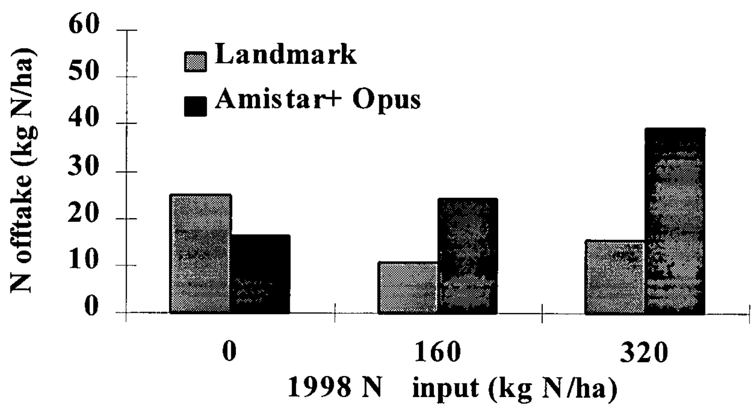

Figure 2. Crop nitrogen offtake (kg N/ha) following treatment with Landmark and Amistar + Opus in comparison with an Opus programme at three levels of nitrogen input.

Anecdotal evidence from farmers during the 1998 season also confirmed that in many cases where strobilurin fungicides had been applied to strips in fields, the same strip in the following crop often appeared paler in colour. As the use of strobilurin fungicides is likely to increase in the future it is important to determine whether their use results in increased nitrogen uptake and differential partitioning of nitrogen in the crop thereby lessening the potential supply of nitrogen to the following crop. In 1996, Sylvester-Bradley found that fertiliser nitrogen positively affected the nitrogen status of the crop following that for which it was applied. Similar information regarding the interaction between applied nitrogen and the use of strobilurins is important to develop strategies to allow better decision making on nitrogen applications to crops following cereals treated with strobilurins. The ADAS study in 1998 (Figures 1 & 2) provided a unique opportunity to investigate the residual effect of strobilurin applications made in 1998 on soil nitrogen availability to the 1999 winter wheat crop. This is additional and complimentary information to the existing HGCA funded project "Exploiting the potential of new fungicide chemicals for improved disease management, crop growth, yield and grain quality" (0026/1/97).

The experiment in 1999 involved growing a field crop of winter wheat, variety Madrigal, on the same area of the nitrogen x fungicide experiment described from 1998. After the harvest of 1998, all the straw residue was removed and the position of the experimental plots marked using metal markers buried in the ground and detectable using a metal detector. The following crop was treated with conventional farm inputs including herbicides, insecticides and fungicides. No nitrogen was applied to the field for the duration of the 1999 experiment.

A range of assessments were carried out on the soil and crop areas sown over the plots which had been previously treated with the four fungicide treatments, untreated, Opus, Landmark and Amistar + Opus at three nitrogen rates, 0, 160 and 320 kg N/ha in 1998. In order to relate the data from the 1999 assessments with the treatments applied in the previous season, figures and tables refer to the fungicide and nitrogen treatments applied in 1998 but must be considered as 'residual' treatments in 1999.

The soil nitrogen supply (SNS) to the 1999 crop was determined from the analysis of soil and crop samples taken in the spring. Statistical analysis of SMN data showed that there was a relatively low level of soil variability and that it was possible to differentiate between nitrogen and strobilurin treatments. This is supported by the work of Webb *et al*, (1998) who found that soil analysis was the most reliable means of predicting soil nitrogen supply. The SNS increased significantly ($P < 0.001$) in relation to the increasing nitrogen input applied in the previous year resulting in maximum values of 104.87, 146.10 and 238.32 kg N/ha (0, 160 and 320 kg N/ha respectively) in the previously untreated crop (Figure 3). The effect of the previous seasons fungicide treatments was also significant ($P = 0.05$) with the use of strobilurins decreasing SNS in relation to both the untreated and the Opus treatment (Figure 3). Differences in SNS between the 0 and 320 kg N/ha nitrogen treatments were 133.45, 124.77, 75.13 and 52.08 kg N/ha following untreated, Opus, Landmark and Amistar + Opus treatments respectively.

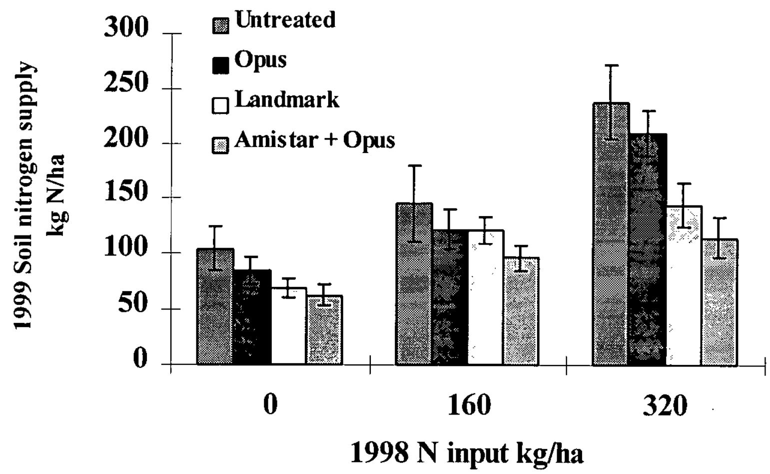

Figure 3. Soil nitrogen supply to the 1999 field crop following treatment of the previous seasons crop with four fungicide treatments (Untreated, Opus, Landmark and Amistar + Opus) at three nitrogen levels (0, 160 and 320 kg N/ha).

Measurements of crop growth were carried out at key growth stages through the season. Samples were taken from four replicate plots and two quadrat samples were taken within each plot, from different sampling positions. At GS75 shoot numbers were found to have increased as the previous years nitrogen input had been increased, with mean shoot numbers of 150, 201 and 276 shoots/m^2 (mean across fungicide treatments) in the 0, 160 and 320 kg N/ha nitrogen treatments (Figure 4). Within each nitrogen input level, shoot numbers from the untreated plots were found to be significantly different from the Opus, Landmark and Amistar + Opus treatments (P = 0.05). There was no significant difference in shoot number between the Opus treatment and the two strobilurin treatments.

At GS39 and 75 measurements of the colour of the flag leaves was determined using a SPAD meter. The SPAD meter measures the transmittance of light through the leaf which relates to its colour, or greenness, which in turn is related to the chlorophyll content of the leaf. As the amount of chlorophyll within a leaf is related to the nitrogen content of that leaf (Ercoli *et al.*, 1993), SPAD measurements may be used as a surrogate for nitrogen assessments. SPAD values for 30 flag leaf samples per plot were measured and are shown in Figure 5. At both GS39 and GS75 there was a significant difference (P <0.001) between SPAD values due to the previous years nitrogen level, with SPAD value increasing with nitrogen input. There was no significant difference due to fungicide treatment at GS39 but there was at GS75, with significantly higher SPAD values in the untreated plots and a significant decrease in SPAD value due to the Amistar + Opus treatment at the highest nitrogen level (320 kg N/ha) (P<0.001)

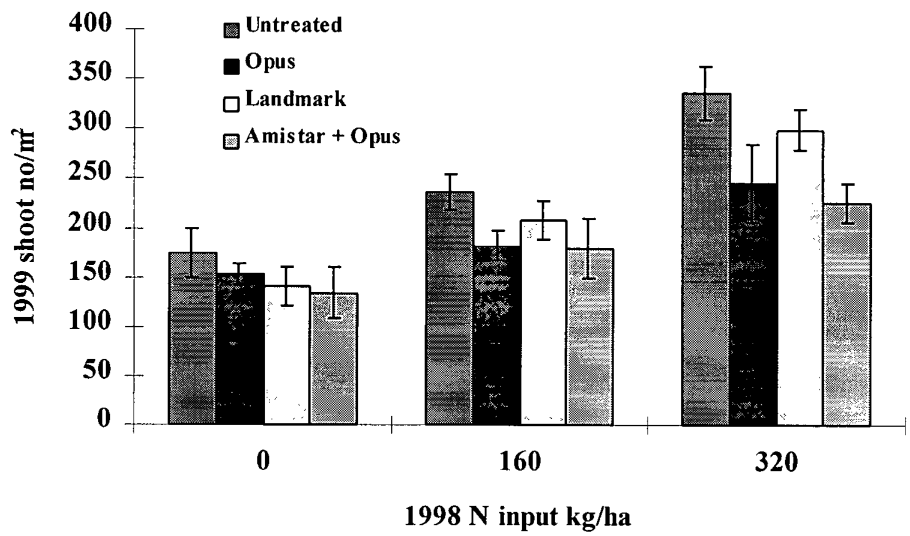

Figure 4. Shoot numbers/m^2 at GS75 in the 1999 field crop following treatment of the previous seasons crop with four fungicide treatments (Untreated, Opus, Landmark and Amistar + Opus) at three nitrogen levels (0, 160 and 320 kg N/ha).

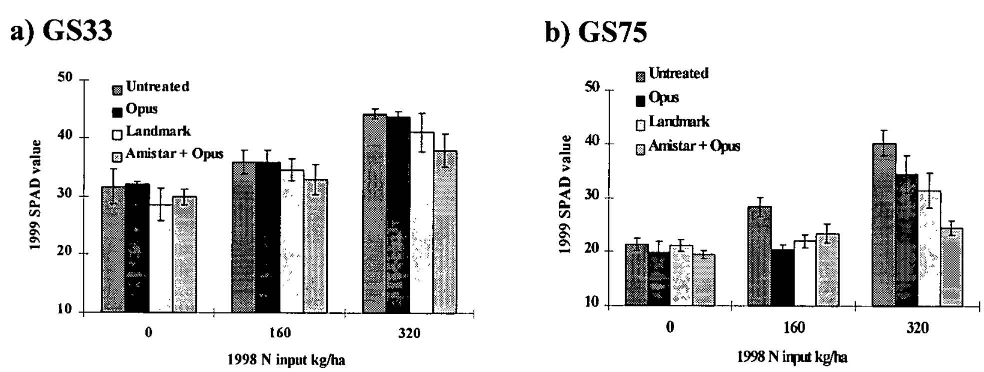

Figure 5. Mean SPAD values of 30 flag leaves per plot on a) GS33 and b) GS75 June following treatment of the previous seasons crop with four fungicide treatments (Untreated, Opus, Landmark and Amistar + Opus) at three nitrogen levels (0, 160 and 320 kg N/ha).

At harvest, measurements of yield components were made including yield, specific weight and the amount of nitrogen in the grain. Both yield and specific weight were found to be significantly different due to both the previous years nitrogen input and fungicide treatment (*P* <0.001) with differences of 0.72, 2.61 and 3.17 t/ha between the untreated and Amistar + Opus treatments at the 0, 160 and 320 kg N/ha nitrogen treatments respectively. The differences in yield and specific weight between fungicide treatment were greatest between the untreated and the other three fungicide treatments. However, yield was 1.67 t/ha lower as a result of the Amistar + Opus treatment compared to the Opus treatment at the highest nitrogen level (Figure 6).

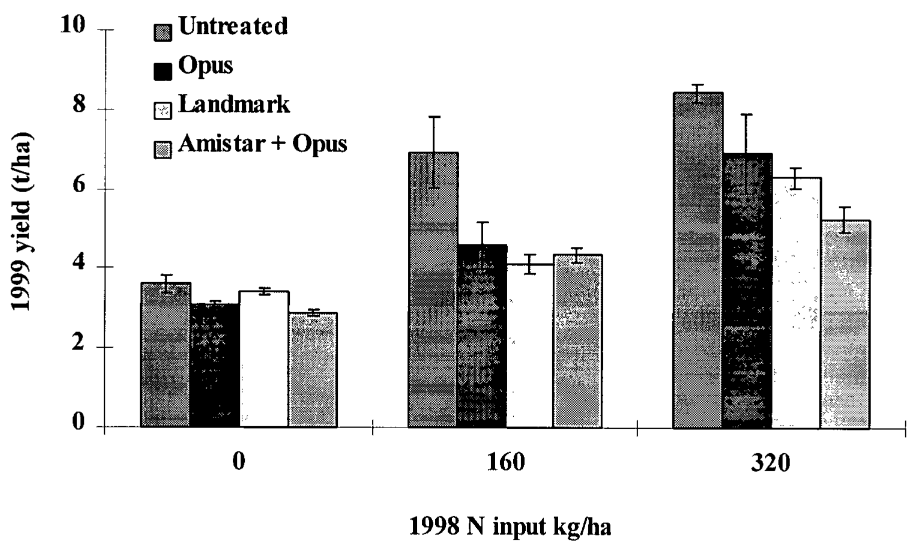

Figure 6. Yield (t/ha) in the 1999 field crop following treatment of the previous seasons crop with four fungicide treatments (Untreated, Opus, Landmark and Amistar + Opus) at three nitrogen levels (0, 160 and 320 kg N/ha).

Nitrogen in the grain at harvest was also found to be significantly different (*P*<0.001) as a result of both the previous seasons nitrogen and fungicide inputs. The Amistar + Opus treatment had significantly lower amounts of nitrogen in the grain than all the other fungicide treatments at all nitrogen levels (*P*<0.001). The difference in grain nitrogen between the untreated and Amistar + Opus, and between Opus and Amistar + Opus, was 22.4, 17.53 and 68.73 kg N/ha and 7.02, 4.61 and 26.27 kg N/ha at nitrogen input levels of 0, 160 and 320 kg N/ha respectively (Figure 7).

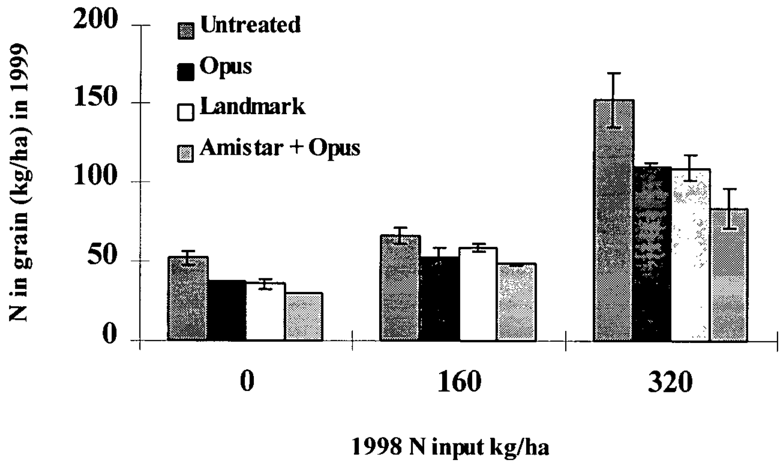

Figure 7. Nitrogen (kg N/ha) in the grain at harvest in the 1999 field crop following treatment of the previous seasons crop with four fungicide treatments (Untreated, Opus, Landmark and Amistar + Opus) at three nitrogen levels (0, 160 and 320 kg N/ha).

The results from this study indicate that both nitrogen and fungicide treatments applied to a crop in one season can have an effect on the crop growth and development, and hence yield, of the following seasons crop. These 'ghosting' effects are generally masked due to the application of nitrogen fertiliser to the second crop in a commercial situation. In this study, in the absence of any nitrogen fertiliser applications, the residual effects of the previous seasons treatments were clearly measurable.

Both the level of nitrogen fertiliser applied and the fungicide applications made to the crop influenced the potential SNS to the following crop. The largest effect on the residual level of nitrogen available to the 1999 crop resulted from the 1998 untreated crop. This was evident from all the crop parameters measured and the yield differences of 0.46, 2.61 and 2.27 t/ha between the untreated and the mean of the three fungicide treatments at 0, 160 and 320 kg N/ha levels respectively.

Differences between SNS following treatments with the three fungicide treatments (Opus, Landmark and Amistar + Opus), were not as great as their mean difference from the untreated at all nitrogen levels. However, SNS was lower in the two strobilurin treatments compared with the Opus treatment at 160 and 320 kg N/ha of nitrogen fertiliser applied (P = 0.05). At 160 and 320 kg N/ha nitrogen input levels, the two strobilurin treatments generally gave lower SPAD values, yields, specific weight and grain nitrogen content than the Opus treatment. The Amistar + Opus treatment consistently had significantly ($P<0.001$) lower SPAD values (30th June), yield and grain nitrogen than the Opus treatment.

It is not possible to elucidate the exact mechanism responsible for the measured differences in remaining SNS, within each nitrogen treatment, following applications of Opus and the two strobilurin fungicides. It may be a result of differences in nitrogen balance i.e. the use of strobilurins fungicides resulted in higher yields and increased nitrogen offtake, this nitrogen offtake accounting for the differences in SNS observed. However, strobilurin treated crops generally have higher total biomass, the residue of which, when incorporated, may alter the carbon:nitrogen (C:N) ratio in the soil. This can reduce nitrogen availability to following crops.

Residual effects of nitrogen are greatly influenced by soil type and the use of organic manures as well as the total level of nitrogen applied. This experiment has clearly demonstrated that on a deep silt soil (ADAS Terrington), there can be marked effects of strobilurin treatment on the nitrogen requirement of the following crops. However, the magnitude of this effect on other soil types is currently unknown and further work on a range of soil types would be necessary before clear guidelines can be produced.

In answer to the original question posed in this study, yes, the use of strobilurin fungicides do generally increase the depletion of soil nitrogen (in nitrogen retentive soils) and are therefore likely to increase the need for nitrogen in the following crop. However, further studies are necessary to compare the residual effects of nitrogen, triazole, strobilurin and new generation strobilurin fungicides on different soil types and to elucidate the mechanisms involved. This would then aid decision making on nitrogen management in the future.

Materials and methods.

Experiment design.

The 1999 experiment was situated on the same area as a nitrogen x fungicide experiment in 1998, at ADAS Terrington, Norfolk. The 1998 experiment was in a fully randomised block design. Differential nitrogen treatments were applied to the 1998 experiment giving total applications of 0, 80, 160, 240 and 320 kg N/ha. Four fungicide treatments were also applied, in all combinations, with the nitrogen treatments, as shown below.

Fungicide	**GS31/32**	**GS33**	**GS39**	**Total**
Landmark	0.67	0.67	0.67	2.0
Amistar +	0.67	0.67	0.67	2.0
Opus	0.25	0.25	0.25	0.75
Opus	0.67	0.67	0.67	2.0
Untreated	0	0	0	0

The 1999 experiment was a field crop of the variety Madrigal sown at 170 kg/ha on the 6th Oct. The site of the 1998 treated plots was identified from metal markers which had been buried in the ground after the 1998 harvest. The position of the previous years plots was then marked to aid sampling. Standard crop husbandry treatments were applied throughout the season except nitrogen, which was not applied.

Soil mineral nitrogen.

In the May 1999, six soil cores per plot were taken to a depth of 90 cm, samples were split into 0-30cm, 30-60cm and 60-90 cm depths, samples at each layer were combined and then analysed in the lab. for % nitrogen.

Crop analysis.

Crop samples were analysed at GS33 to determine crop N offtake to calculate SNS, and at GS39 and GS75 to determine crop nitrogen offtake (kg N/ha), shoot number (m^{-2}), SPAD value and total biomass (t/ha). Two 0.25 m^2 quadrat samples were taken from opposite ends of each experimental plot from the four fungicide treatments at 1998 nitrogen inputs of 0,160 and 320 kg N/ha. The total fresh weight and number of potentially fertile shoots of the crop sample were recorded. The sample was then randomly split into two sub samples - SS1 and SS2. The SS1 sub-sample was retained for the determination of total dry weight. The fresh weight of SS1 was recorded, the sample was then cut up into 10cm lengths and oven dried at 80° C for 48 hr. The dry weight of SS1 was then recorded and samples analysed in the lab. for % nitrogen.

The SS2 sample was retained for the determination of the SPAD value. Three groups of ten shoots were selected from the SS2 sample. For each group of ten shoots the SPAD value of the top fully emerged leaves was measured. The mean value for each group of ten was then recorded.

Grab samples.

Grab sample analysis was carried out in order to determine thousand grain weight (g), mean grain weight (g), total grain yield (t/ha), total above ground biomass (t/ha), grain nitrogen content and nitrogen harvest index. Prior to harvest grab samples of approximately 100 shoots were taken from the plots treated in 1998 with the four fungicide treatments at the nitrogen input levels of 0, 160 and 320 kg N/ha. In the lab. the fresh weight and shoot number of the whole sample was recorded. All the ears were removed and counted. The remaining straw was randomly sub sampled and the fresh weight recorded. The straw sub sample was oven dried at 80° C for 48 hr and the dry weight recorded. The ears were also oven dried and the dry weight recorded. The ears were then threshed and the grain weight recorded. The number of grains in a weighed sub sample was then determined. Grain samples were analysed in the lab. for % nitrogen.

Harvest

Experimental plots were combine harvested on 3rd August, 1999.

Results.

The yield response experiment in 1998 was not part of this HGCA funded project, however, the data do establish the basis for the 1999 experiment. Yield response and crop nitrogen offtake for the 1998 experiment are given in Figures 1 & 2.

Soil mineral nitrogen

Soil samples were not taken until May due to difficult weather conditions at the experimental site. By this time, crop development had reached GS33 and it was likely that a large proportion of the nitrogen in the soil had been taken up. Data from the soil analyses confirmed this as no significant difference was found between the 1998 nitrogen treatments, however, the level of SMN in the soil as a result of the 1998 fungicide treatments was significantly different (P=0.05) (Table 1).

	1998 Nitrogen input (kg N/ha)		
1998 Fungicide treatment	0	160	320
Untreated	44.7	31.6	49.2
Opus	32.1	23.2	31.8
Landmark	31.1	35.6	34.1
Amistar + Opus	25.7	35.3	26.7

	s.e.d	*F pro*
Nitrogen (N)	3.59	n.s.d.
Fungicide (F)	4.15	0.05
F x D	7.19	n.s.d
df	22	
% CV	26.3	

Table 1. 1999 soil mineral nitrogen (kg N/ha) in plots following treatment with 0, 160 and 320 kg N/ha, and four fungicide treatments (Untreated, Opus, Landmark and Amistar + Opus), in 1998.

Soil nitrogen supply (SNS)

The soil nitrogen supply (SNS) to the 1999 crop was calculated from the analysis of soil mineral nitrogen and the crop nitrogen offtake at GS33. The SNS increased significantly ($P < 0.001$) in relation to the increasing nitrogen input applied in the previous year resulting in maximum values of 104.87, 146.10 and 238.32 kg N/ha (0, 160 and 320 kg N/ha respectively) in the previously untreated crop (Figure 3). The effect of the previous seasons fungicide treatments was also significant ($P = 0.05$) with the use of strobilurins decreasing SNS in relation to both the untreated and the Opus treatment (Figure 3). Differences in SNS between the 0 and 320 kg N/ha nitrogen treatments were 133.45, 124.77, 75.13 and 52.08 kg N/ha following untreated, Opus, Landmark and Amistar + Opus treatments respectively.

Crop growth analysis

At GS75 shoot numbers were found to have increased as the previous years nitrogen input had been increased, with mean shoot numbers of 150, 201 and 276 shoots/m^2 (mean across fungicide treatments) in the 0, 160 and 320 kg N/ha nitrogen treatments (Figure 4). Within each nitrogen input level, shoot numbers from the untreated plots were found to be significantly different from the Opus, Landmark and Amistar + Opus treatments ($P = 0.05$). There was no significant difference in shoot number between the Opus treatment and the two strobilurin treatments.

Crop nitrogen offtake at GS39 increased significantly due to the previous years nitrogen treatment in the fungicide untreated plots, compared with the mean of the three 1998 fungicide treated plots, by 17.1, 32.4 and 63.2 kg N/ha in the 0, 160 and 320 kg N/ha treatments respectively ($P < 0.001$) (Table 2). Differences in nitrogen offtake were also significant due to fungicide input, with the amount of nitrogen offtake being lowest following the previous years application of Amistar + Opus, at all levels of nitrogen input (Table 2).

At GS39 and 75 measurements of the colour of the flag leaves was determined using a SPAD meter. There was no significant difference due to fungicide treatment at GS39 but there was at GS75, with significantly higher SPAD values in the untreated plots and a significant decrease in SPAD value due to the Amistar + Opus treatment at the highest nitrogen level (320 kg N/ha) ($P < 0.001$) (Figure 5).

	1998 Nitrogen input (kg N/ha)		
1998 Fungicide treatment	0	160	320
Untreated	60.2	114.5	189.1
Opus	53.2	98.7	178.3
Landmark	38.6	86.5	110.7
Amistar + Opus	37.4	61.0	88.6

	s.e.d	*F pro*
Nitrogen (N)	12.81	<0.001
Fungicide (F)	14.79	0.05
F x D	25.63	n.s.d
df	22	
% CV	33.7	

Table 2. 1999 crop nitrogen offtake (kg N/ha) at GS33 in plots following treatment with 0, 160 and 320 kg N/ha, and four fungicide treatments (Untreated, Opus, Landmark and Amistar + Opus), in 1998.

Grab sample and harvest data

At harvest, measurements of yield components were made including yield, specific weight and the amount of nitrogen in the grain. Both yield and specific weight were found to be significantly different due to both the previous years nitrogen input and fungicide treatment (P <0.001) with differences of 0.72, 2.61 and 3.17 t/ha between the untreated and Amistar + Opus treatments at the 0, 160 and 320 kg N/ha nitrogen treatments respectively. The differences in yield and specific weight between fungicide treatment were greatest between the untreated and the other three fungicide treatments (Tables 3 & 4). However, yield was 1.67 t/ha lower as a result of the Amistar + Opus treatment compared to the Opus treatment at the highest nitrogen level (Figure 6). Nitrogen in the grain at harvest was also found to be significantly different (P<0.001) as a result of both the previous seasons nitrogen and fungicide inputs. The Amistar + Opus treatment had significantly lower amounts of nitrogen in the grain than all the other fungicide treatments at all nitrogen levels (P<0.001). The difference in grain nitrogen between the untreated and Amistar + Opus, and between Opus and Amistar + Opus, was 22.4, 17.53 and 68.73 kg N/ha and 7.02, 4.61 and 26.27 kg N/ha at nitrogen input levels of 0, 160 and 320 kg N/ha respectively (Figure 7).

1998 Fungicide treatment	1998 Nitrogen input (kg N/ha) 0	160	320
Untreated	3.59	6.94	8.43
Opus	3.09	4.57	6.92
Landmark	3.41	4.09	6.29
Amistar + Opus	2.87	4.33	5.26

	s.e.d	*F pro*
Nitrogen (N)	0.33	<0.001
Fungicide (F)	0.38	<0.001
F x D	0.67	n.s.d.
df	22	
% CV	16.3	

Table 3. 1999 combine yield (t/ha) in plots following treatment with 0, 160 and 320 kg N/ha, and four fungicide treatments (Untreated, Opus, Landmark and Amistar + Opus), in 1998.

1998 Fungicide treatment	1998 Nitrogen input (kg N/ha) 0	160	320
Untreated	75.81	77.15	79.29
Opus	74.20	72.51	74.73
Landmark	76.30	76.15	78.26
Amistar + Opus	68.97	77.82	76.47

	s.e.d	*F pro*
Nitrogen (N)	0.73	<0.001
Fungicide (F)	0.84	<0.001
F x D	1.46	0.05.
df	22	
% CV	2.4	

Table 4. 1999 specific weight (kg/hl) in plots following treatment with 0, 160 and 320 kg N/ha, and four fungicide treatments (Untreated, Opus, Landmark and Amistar + Opus), in 1998.

Conclusion.

The results from this study indicate that both nitrogen and fungicide treatments applied to a crop in one season can have an effect on the crop growth and development, and hence yield, of the following seasons crop. Both the level of nitrogen fertiliser applied and the fungicide applications made to the crop influenced the potential SNS to the following crop. The largest effect on the residual level of nitrogen available to the 1999 crop resulted from the 1998 untreated crop. This was evident from all the crop parameters measured and the yield differences of 0.46, 2.61 and 2.27 t/ha between the untreated and the mean of the three fungicide treatments at 0, 160 and 320 kg N/ha levels respectively.

Differences between SNS following treatments with the three fungicide treatments (Opus, Landmark and Amistar + Opus), were not as great as their mean difference from the untreated at all nitrogen levels. However, SNS was lower in the two strobilurin treatments compared with the Opus treatment at 160 and 320 kg N/ha of nitrogen fertiliser applied (P = 0.05). It is not possible to elucidate the exact mechanism responsible for the measured differences in remaining SNS, however, one explanation may be differences in nitrogen balance. Also, strobilurin treated crops generally have higher total biomass, the residue of which, when incorporated, may alter the carbon:nitrogen (C:N) ratio in the soil. This can reduce nitrogen availability to following crops.

Residual effects of nitrogen are greatly influenced by soil type and the use of organic manures as well as the total level of nitrogen applied. This experiment has clearly demonstrated that on a deep silt soil (ADAS Terrington), there can be marked effects of strobilurin treatment on the nitrogen requirement of the following crops. However, the soil at Terrington is at the extreme of nitrogen 'retentiveness' and the magnitude of this effect on other soil types is currently unknown. Further work on a range of soil types would be necessary before clear guidelines can be produced.

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