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Abstract and Summary

‘Canopy management’ and late nitrogen applications to improve yield of oilseed rape

by

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Contents

1. Abstract

Previous HGCA-funded work demonstrated that oilseed rape yield is reduced by the development of an over-large canopy. This project further developed and tested Canopy Management principles that will help growers achieve an optimum sized canopy through the correct timing and rate of nitrogen (N) fertiliser. Canopy Management involves measuring the amount of N in the soil and crop in February (soil N supply – SNS) and then applying sufficient N to build an optimum sized canopy with a green area index of 3.5 units by flowering followed by variable amounts of late N applied between yellow bud and early flowering depending on yield potential. When the SNS was moderate or high the first N application made to the Canopy Managed treatments was at the 2nd conventional split timing (start of stem extension, end March/early April). When the SNS was low a small proportion of N was applied at the 1st conventional split (end February/early March). During the project, methods were developed to calculate what proportion of N must be applied early for crops with a small SNS. Experiments were set up in 2005/6, 2006/7 and 2007/8 at ADAS Boxworth, High Mowthorpe and Rosemaund. Each experiment included two varieties (Winner and 'low biomass' variety Castille), grown at seven N rates (0 to 360 kg/ha) applied at Conventional timings (50% in late Feb/early March and 50% in late March) and Canopy Management timings, with and without Folicur applied at green bud.

The project showed that delaying N through using Canopy Management principles increased yield by up to 0.36 t/ha in situations where the crop would have produced an over-large and lodging-prone canopy. The yield increases were associated with reduced stem growth leading to shorter plants and less lodging, and possibly increased seed set. Methods of employing Canopy Management were developed so that they are applicable for all types of crop, including low biomass varieties and crops with a small SNS. The assumptions that underlie Canopy Management were validated within the study. Using the Canopy Management principles to calculate the N fertiliser requirement was shown to be accurate across sites and seasons, and more accurate than RB209 guidelines. The application of Folicur at green bud increased yield by up to 0.32 t/ha and resulted in average yield increases across the nine experiments of 0.15 t/ha for Winner and 0.10 t/ha for Castille, in the presence of minimal amounts of disease. Using Canopy Managed N timings did not affect the size of the yield response to Folicur. Results from this project have been used to develop the 'N-Calc' fertiliser recommendation system run by Growhow UK Ltd and to help revise the current RB209 guidelines.

2. Summary

2.1 Introduction

The current recommendations for N fertiliser applications to oilseed rape (RB209) were formulated in the late 1980s on varieties such as Rafal and Ariana. Since then the average yield of oilseed rape varieties in the Recommended List trials have increased from 3.7 t/ha to 4.8 t/ha, with the best varieties yielding more than 5 t/ha. Alterations in N management may be required to realise the high yield potential of new varieties. Conventional RB209 recommendations are for N to be applied in two splits at the end of February/early March and end of March/early April. N is sometimes applied as early as late January/early February. Previous HGCA-funded work demonstrated that yield is reduced by the development of an over-large canopy at flowering (Project Report OS49). This may arise from too much early N, from early or overly dense plant establishment or from mild autumn and winter conditions. The result of this is a thick flower layer reflecting much of the incoming light which causes few seeds to be set and a low yield potential. Canopy size can be optimised by adjusting the timing and rate of N to the size of the crop and the soil N supply. Nitrogen is a particularly valuable tool for avoiding the production of over-large canopies which may arise from uncontrollable factors such as mild autumn and winter conditions or high soil nitrogen supply.

2.2 Aim and objectives

2.2.1 Project Aim

Develop nitrogen management strategies that help to realise the high yield potential of modern oilseed rape varieties.

2.2.2 Specific Objectives

I. Understand the physiological mechanisms by which a canopy management approach to N use increases yield.

II. Understand how the canopy management approach may need adjusting for different types of crop.

2.3 Materials and Methods

2.3.1 Canopy Management approach

Previous HGCA-funded work has demonstrated that oilseed rape must achieve an optimum green area index (GAI) of 3.5 units at flowering and the crop must take up 50 kg N/ha to build each unit of GAI. This means that the crop must take up 175 kg N/ha to achieve the optimum GAI of 3.5. Canopy Management principles assume that any N that the crop has taken up by the end of winter remains in the crop until flowering and therefore contributes to the production of the optimum GAI. The principles also assume that oilseed rape takes up 100% of the soil mineral N measured in the soil in February and 60% of any fertiliser N applied (55% on shallow soils over chalk or limestone). These uptake efficiencies are similar to average figures that have been measured in wheat. The rate of crop N uptake is assumed to be 3 kg N per ha per day from the start of active spring growth until flowering. It was expected that crops with a higher than average yield potential will require additional N which should be applied between yellow bud and mid-flowering to avoid this additional N causing the optimum canopy size to be exceeded.

In early February, the amount of N in the soil and crop were measured and this was used to calculate how much fertiliser N was required for the crop to achieve a GAI of 3.5 using the assumptions described above.

Example: In February the amount of N in the soil was 50 kg N/ha and the amount of N in the crop was 50 kg N/ha. It is assumed that by flowering the crop will contain all of this soil and crop N (100 kg N/ha). This means it will be 75 kg N/ha short of the amount required for the optimum GAI. At 60% efficiency, 125 kg of fertiliser N must be applied to make up this shortfall.

In general the fertiliser N required to achieve the optimum sized canopy was applied at the 2nd conventional split timing at the start of stem extension (late March/early April). A small proportion of the N was applied at the 1st conventional split timing (late February/early March) when it was calculated that there would be insufficient time (assuming an uptake of 3 kg/ha/day) for the crop to take up all of the N required to achieve an optimum sized canopy by mid flowering if the first application was delayed. Additional N for high yield potential was applied at yellow bud to mid flowering.

2.3.2 Field experiments

2.3.2.1 Sites

Experiments were carried out in 2005/6, 2006/7 and 2007/8. Experiments were drilled at ADAS Boxworth in Cambridgeshire (Clay, Hanslope series), ADAS High Mowthorpe in N. Yorkshire (shallow silty clay loam over chalk, Andover series) and ADAS Rosemaund in Herefordshire (silty clay loam, Bromyard series).

2.3.2.2 Experimental factors and design

Four factors were investigated; variety, N rate, N timing and a growth regulatory fungicide Folicur. At each site the variety, N rate and N timing treatments were fully randomised within each of four replicate blocks, apart from Boxworth and High Mowthorpe in 2006 in which variety formed main plots within which the N rate and N timing were randomised. At each site Folicur was then applied across one half of each block and the position of the Folicur strip was randomised for each block. Each individual plot measured 18 m by 3.5 m.

The two varieties used were Winner and the 'low biomass' variety Castille. Seven N rates were used (0, 60, 120, 180, 240, 300, 360 kg/ha). All N was applied as ammonium nitrate (34.5% N) at either Conventional or Canopy Managed timings. Conventional timings were for 50% of the N applied in late February/early March and 50% applied at the start of stem extension (late March/early April). Canopy Management timings were for all, or the majority, of the N required to achieve the optimum sized canopy to be applied at the 2nd conventional split timing (start of stem extension) and the remaining N was applied between yellow bud and mid-flowering. The Folicur treatment was applied at green bud. The rate of Folicur was dependent on the size of the crop canopy measured in February. Crops with a GAI of less than 1 received 0.5 l/ha and crops with a GAI of 1 or more received a rate of 1.0 l/ha. Fungicides without growth regulatory activity were used to minimise disease. Adequate Sulphur was ensured by applying 75 kg/ha SO_3 as Magnesium Sulphate (Kieserite) to all treatments at the same time as the first N split was applied.

2.3.2 Measurements

Assessments included the amount of mineral N in the soil, together with the GAI and N content of the crop, in February. At flowering, the crop height, light interception/reflection, GAI, biomass and crop N content were measured. At crop maturity the biomass and N content of the stem, pod walls and seeds were measured.

Pod greenness and lodging were assessed at regular intervals. Yield was determined for all treatments using a small plot combine from an area of at least $30m^2$ and the moisture content and oil content of the seed was measured.

2.3.3 Calculations and Statistics

Analysis of variance procedures within Genstat (8.1) (www.genstat.com) were used to calculate whether treatments were significantly different. Linear plus exponential N response curves were fitted to the seed yield data. The economically optimum N rate was calculated using a breakeven ratio of 2.5 because this has previously been used as a standard for fertiliser recommendations. The gross margin over N costs was calculated by assuming a seed yield price of £230/t (9% moisture), ammonium nitrate containing 34.5% N costing £200/t (which were typical average prices during the project and these give a breakeven ratio of 2.5). The oil premium was calculated as 1.5% of the basic oilseed rape price for each percentage point that the oil content was above 40%.

2.4 Results

2.4.1 Effects of Canopy Management on yield

The regression analyses showed that the Canopy Managed and Conventional N strategies did not result in significantly different N optima in any of the experiments. In the 2005/6 season the Canopy Management approach increased yield over the Conventionally-timed N treatments at the sites with a moderate or large combined supply of N in the soil and crop in February (soil N supply – SNS). The yield of Winner was increased by 0.36 t/ha at Boxworth and 0.15 t/ha at Rosemaund, and the yield of Castille was increased by 0.10 t/ha at Boxworth with no effect at Rosemaund (Table 2.1). The yield increases were associated with reduced lodging as a result of stem shortening. In later experiments measurements showed that Canopy Management reduced height by up to 10 cm. Canopy Management was also shown to reduce the size of the canopy at flowering. This will have helped the crops, which would otherwise have produced an over-large canopy, to achieve the optimum sized canopy and set more seeds/m^2. At High Mowthorpe the SNS was just 67 kg/ha and the Canopy Management approach had no effect on Winner and slightly reduced the yield of Castille. This result demonstrated that a greater proportion of N must be applied early to crops with a small SNS to give the crop sufficient time to take up enough N by flowering to achieve the optimum GAI. This was used to modify the Canopy

Management approach for later experiments. Although there was no significant interaction between Folicur and N management, the Folicur did appear to increase the yield of Conventionally-managed crops at Rosemaund and Boxworth more than the Canopy Managed crops. There was, however, no significant interaction between N rate and Folicur. Folicur did significantly increase the yield of both conventional and Canopy Managed treatments at High Mowthorpe, which was probably due to an effect on light leaf spot rather than a PGR effect.

Table 2.1. 2005/6 experiment summary.

	BX06		HM06		RM06	
†Jan/Feb soil mineral N (kg/ha)	50		35		60	
Jan/Feb crop N content (kg/ha)	72		32		33	
Jan/Feb GAI	1.40		0.57		0.63	
N timing strategy	Conv	CM	Conv	CM	Conv	CM
Optimum N rate (kg/ha)	70	70	239	239	224	224
N rate at 1st split (end Feb/early March)	35	0	120	40	112	0
N rate at 2nd split (early stem ext.)	35	70	119	140	112	140
N rate at 3rd split (yellow bud to mid flower)	0	0	0	59	0	84
Yield at opt N Winner (t/ha)	3.40	3.76	3.69	3.62	4.40	4.55
Yield at opt N Winner + Folicur (t/ha)	3.60	3.74	3.86	3.89	4.62	4.58
Yield at opt N Castille (t/ha)	4.04	4.12	4.56	4.43	4.90	4.91
Yield at opt N Castille + Folicur (t/ha)	4.19	4.31	4.84	4.74	4.99	4.92

†Measured to 90 cm at Boxworth and Rosemaund and 60 cm depth at High Mowthorpe.
Conv – conventional N timing strategy; CM – Canopy Managed N timing strategy.

In the 2006/7 season, the crops at each site had moderate to large canopies in February and in a typical season would have been expected to produce over-large canopies and to benefit from a Canopy Managed approach. However, negligible rainfall between the end of March and early May restricted canopy growth which resulted in moderate sized canopies at flowering. Across all the treatments at Boxworth, Canopy Management increased yield slightly by 0.08 t/ha (P=0.082). This advantage was greater at high N rates and for Winner, for example at 300 and 360 kg N/ha Canopy Manegement gave a 0.28 t/ha yield advantage. The yield increase was shown to result from less early lodging as a result of crop shortening and a small increase in seeds/m^2 which was probably caused by achieving a canopy size at flowering that was closer to the optimum. At Rosemaund Canopy Management did not affect yield despite the very dry spring. There was no effect on yield because Canopy Management reduced the size of the canopy at flowering from above the optimum to slightly below the optimum, and because there was only slight lodging at this site. At High Mowthorpe Canopy Management reduced yield by 0.14 t/ha. The spring drought was most severe at this site which resulted in the development of a sub-optimal canopy at flowering. Canopy Management reduced the canopy size further and this resulted in slightly fewer seeds/m^2 set. Folicur significantly increased yield on Winner but not Castile at High Mowthorpe and Rosemaund but had no significant effect on yield at Boxworth.

Table 2.2. 2006/7 experiment summary.

	BX07		HM07		RM07	
†Jan/Feb soil mineral N (kg/ha)	43		58		54	
Jan/Feb crop N content (kg/ha)	92		54		61	
Jan/Feb GAI	2.37		1.21		2.08	
N timing strategy	Conv	CM	Conv	CM	Conv	CM
Optimum N rate (kg/ha)	54	54	156	156	165	165
N rate at 1st split (end Feb/early March)	0	27	78	0	83	0
N rate at 2nd split (early stem ext.)	54	27	78	120	83	100
N rate at 3rd split (yellow bud to mid flower)	0	0	0	36	0	65
Yield at opt N Winner (t/ha)	3.05	3.05	4.50	4.31	4.66	4.66
Yield at opt N Winner + Folicur (t/ha)	2.90	3.06	4.64	4.42	4.88	4.84
Yield at opt N Castille (t/ha)	3.66	3.63	5.20	5.12	5.04	4.99
Yield at opt N Castille + Folicur (t/ha)	3.51	3.63	5.17	5.10	5.09	5.11

†Measured to 90 cm at Boxworth and Rosemaund and 60 cm depth at High Mowthorpe.
Conv – conventional N timing strategy; CM – Canopy Managed N timing strategy.

In the 2007/8 season the crops at Boxworth and High Mowthorpe were very small in February following slow emergence during the dry autumn and had a modest amount of mineral N in the soil. After the first year the Canopy Management approach was further developed to be applicable for crops with a small SNS by including an estimate of the latest date when the N should start to be applied to give the crop sufficient time to build the optimum sized canopy. This assumed a rate of crop N uptake of 3 kg N/ha. Based on this 40 to 60 kg N/ha was applied at the first Conventional split timing (early March) at these sites compared with 118 to 128 kg N/ha for the Conventional strategy. Overall, there were no differences in yield between the two strategies at Boxworth and High Mowthorpe indicating that the Canopy Management strategy is appropriate for crops with a small SNS. The crop at Rosemaund also had a small SNS, but with a moderate sized canopy and a very small amount of soil N. The original Canopy Management principles were tested at this site with all of the N required for the optimum canopy applied at the 2nd Conventional split timing (31 March). At this site Canopy Management did not affect the yield of Winner and reduced the yield of Castille by 0.29 t/ha. If the modified Canopy Management principles had been applied then 50 kg N/ha would have been applied in early March which is likely to have prevented any yield penalty and may have increased the yield of Winner. At Rosemaund, Folicur significantly increased the yield of Winner by 0.20 t/ha and had no effect on Castille. At High Mowthorpe, Folicur increased yield by 0.3 t/ha, although this was not statistically significant, and there was no significan effect at Boxworth.

Table 2.3. 2007/8 experiment summary.

	BX08		HM08		RM08	
†Jan/Feb soil mineral N (kg/ha)	58		38		12	
Jan/Feb crop N content (kg/ha)	8		10		50	
Jan/Feb GAI	0.19		0.10		1.36	
N timing strategy	Conv	CM	Conv	CM	Conv	CM
Optimum N rate (kg/ha)	256	256	236	236	128	128
N rate at 1st split (end Feb/early March)	128	40	118	60	64	0
N rate at 2nd split (early stem ext.)	128	180	118	170	64	128
N rate at 3rd split (yellow bud to mid flower)	0	36	0	6	0	0
Yield at opt N Winner (t/ha)	3.82	3.80	3.42	3.43	4.01	3.98
Yield at opt N Winner + Folicur (t/ha)	3.84	3.92	3.76	3.65	4.20	4.18
Yield at opt N Castille (t/ha)	4.00	3.99	3.78	3.78	4.49	4.21
Yield at opt N Castille + Folicur (t/ha)	4.06	4.10	4.04	4.16	4.45	4.14

†Measured to 90 cm at Boxworth and Rosemaund and 60 cm depth at High Mowthorpe.
Conv – conventional N timing strategy; CM – Canopy Managed N timing strategy.

2.4.2 Testing the Canopy Management principles

2.4.2.1 Soil N uptake efficiency

The efficiency with which the crop took up soil N was calculated by dividing the amount of N taken up by the unfertilised crop at harvest by the amount of mineral N measured in the soil (to 60 or 90cm) and the crop N in February. On average the efficiency with which soil N was taken up was estimated to be 107% (Figure 2.1) and there were no systematic differences between the sites or seasons. Several of the experiments had soil N uptake efficiency values of more than 100%, which may simply be the result of sampling variation or may indicate that these crops took up some N which was mineralised after February. In 2008, it was possible to compare the two varieties and this showed that Castille had greater soil N uptake efficiency at each site with an average soil N uptake efficiency of 130% compared with 113% for Winner.

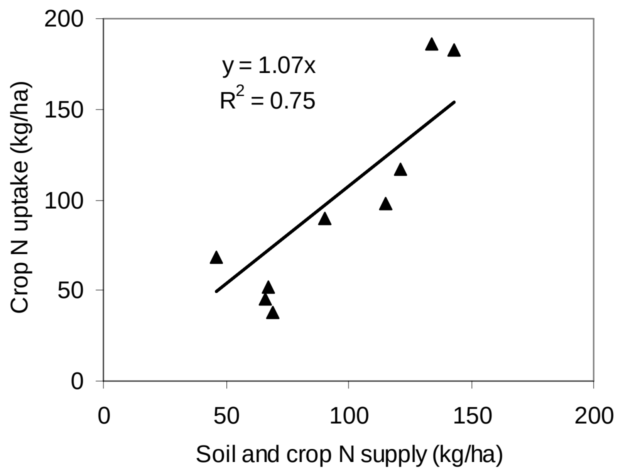

Figure 2.1. Relationship between the combined soil mineral N and crop N measured in February and the crop N uptake at harvest for crops grown at Boxworth, High Mowthorpe and Rosemaund in 2006, 2007 and 2008.

2.4.2.2 Fertiliser N uptake efficiency

The equivalent efficiency with which fertiliser N was taken up by the crop was calculated by subtracting the N taken up by the crop without fertiliser from the N taken up with fertiliser and dividing by the rate of fertiliser N applied. At the N rate that was closest to the economic optimum (167 kg N/ha on average) the fertiliser N uptake efficiency was calculated at 57%. The coefficient of variation of the fertiliser uptake efficiency across the 24 crops was 23%. Across the 3 sites, the fertiliser N uptake efficiency was lower in 2008 (47%) compared with 63% in 2006 and 63% in 2007. There were no systematic differences between sites or between the Canopy Managed and Conventional N timings. At a lower average fertiliser N rate of 100 kg N/ha the fertiliser N uptake efficiency was 67%. At 240 kg N/ha the average Fertiliser N uptake efficiency was 43%. These differences emphasise the importance of calculating the N uptake efficiency at the economically optimum N rate. The combined efficiency with which the soil N and optimum fertiliser N rate were taken up was 77% across all of the crops that were analysed in this study.

2.4.2.3 Relationship between GAI and crop N content

In February, crops with a GAI of between 0.1 and 1.5 contained 49 kg N per unit of GAI (Figure 2.2). Crops with GAIs of between 1.5 and 2.5, which were measured at Rosemaund and Boxworth in 2007 and Rosemaund in 2008, contained about 40 kg N per unit of GAI on average. These crops grew in seasons with a mild autumn and winter which increased the rate of over winter growth and it is possible that the tissue N concentration becomes diluted under these conditions. For crops measured at mid-flowering in 2007 and 2008 and the end of flowering in 2006, each unit of GAI up to the target GAI of 3.5 contained 43 kg N/ha (Figure 2.3). The slope of this regression line was not significantly different from a slope of 50 kg N per unit of GAI. There was no significant difference in the amount of N contained within each unit of GAI between N rate, variety, site or year. These results generally support the assumption that each unit of GAI contains 50 kg N/ha. However further work should test whether large canopies in February resulting from a mild autumn/winter contain less than 50 kg N/ha.

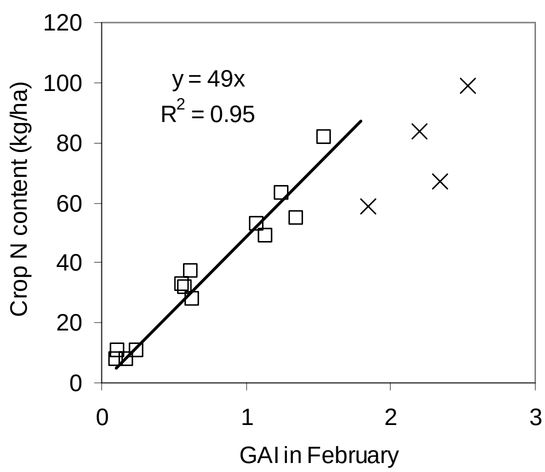

Figure 2.2. Relationship between GAI and crop N content measured in February Crops of GAI 1.5 or below (squares), crops above GAI 1.5 (crosses).

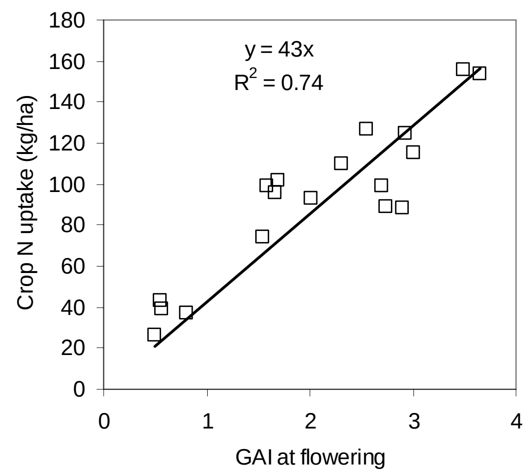

Figure 2.3. Relationship between GAI and crop N content at flowering.

2.4.2.4 Relationship between N requirement and yield

Whether or not the yield potential of each site affected the N supply required to achieve the yield potential was investigated by comparing the yield at the economic optimum (as calculated from the N response curves) with the supply of N available for crop uptake (100% of soil and crop N in February and 60% of the optimum fertiliser N) (Figure 2.4) to account for differences in residual soil N between sites. Data from an additional nine N response experiments from Growhow UK Ltd were also included in the analysis. The regression analysis showed that each additional tonne of yield required an additional 36 kg/ha of crop available N. It is estimated that this would be equivalent to 36 kg/ha of soil mineral N or 60 kg/ha of fertiliser N for each additional tonne of yield.

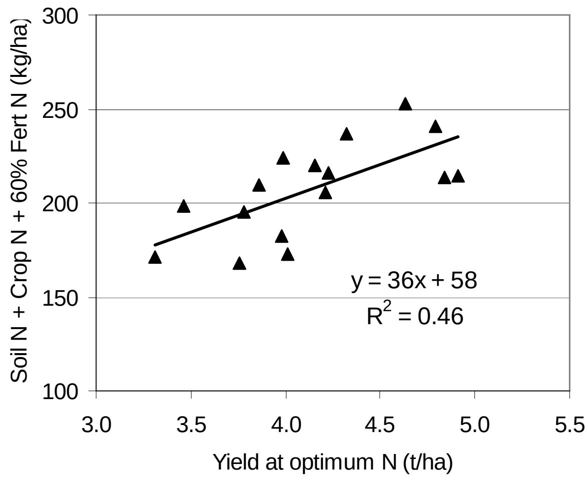

Figure 2.4. Relationship between the yield at the economic optimum N rate and the supply of N that is available for crop uptake. Each point represents data from an N response experiment.

2.4.3 Predicting fertiliser N requirement

The Canopy Management principles predict the optimum amount of fertiliser N based on measurements of the soil and crop N in February, a realistic estimate of the potential yield, together with assumptions about the efficiencies with which the crop takes up N from the soil and fertiliser. The accuracy of these principles for predicting N optima were tested retrospectively for each experiment described in this study and nine N response experiments from GrowHow. The accuracy of the RB209 guidelines; 1) using the book values to estimate the SNS and 2) using measured values of SNS were also tested. The tests showed that the Canopy Management principles were the most accurate method of predicting the optimum N rate with an average error of +/- 32 kg N/ha for yield (Table 2.4). RB209 guidelines with measurements of soil and crop N had an average error of 39 kg N/ha and 35 kg N/ha after accounting for the oil premia. Relying on RB209 look up tables to estimate the SNS, rather than taking a measurement, significantly increased the error to between 48 and 59 kg N/ha.

Table 2.4. Average error in the prediction of the fertiliser N requirement (kg N/ha).

	Optimum yield	Optimum yield after accounting for oil premia
RB209	+/- 48	+/- 59
RB209 with soil N measurements	+/- 39	+/- 35
Canopy Management	+/- 32	+/- 32

Based on 18 N response experiments between 2006 and 2008.

2.4.4 Folicur

Folicur applied at the green bud stage at a rate of 0.5 l/ha or 1.0 l/ha increased yield by up to 0.32 t/ha and did not cause any significant yield reductions. On average across all experiments Folicur increased the yield of Winner by 0.15 t/ha and Castille by 0.10 t/ha. Disease was minimised in all experiments using fungicides without growth regulatory activity. The effect of Folicur was generally the same for Canopy Managed or Conventional N timings. At the sites where Folicur significantly increased yield there was usually a significant reduction in lodging caused by Folicur. The reductions in lodging were at least partially caused by reductions in height of between 3 and 10 cm. There was no evidence of any differential height reduction between Canopy Management and Conventional N timings or between Winner and Castille. Greater height reductions occurred at higher N rates in only one experiment. It is possible that part of the yield increases were also caused by the Folicur treatment increasing the number of seeds set as a result of reducing the amount of light absorbed and reflected by the flowers.

2.5 Conclusions

- Delaying N through using Canopy Management principles increased yield by up to 0.36 t/ha in situations where the crop would have produced an over-large and lodging-prone canopy.
- Following modifications to account for the start date for N application the Canopy Management approach was shown to be robust both with backward crops and where dry conditions in the spring delayed N uptake.
- The yield increase has been shown to be associated with reduced stem growth leading to shorter plants and less lodging, and possibly increased seed set.
- Methods of employing the Canopy Management principles have been developed so that they are applicable for all types of crop including low biomass varieties and crops with small amounts of N in the crop and soil in February.

- The assumptions that underlie Canopy Management have been validated within the series of experiments carried out within this study.
- Using the Canopy Management principles to calculate the N fertiliser requirement based on the amount of N in the crop and soil in the spring, together with the yield potential, is accurate across sites and seasons, and more accurate that RB209 guidelines.
- The application of Folicur at green bud resulted in average yield increases across the 9 experiments in the presence of minimal amounts of disease of 0.15 t/ha for Winner and 0.10 t/ha for Castille. Using Canopy Managed N timings did not affect the size of the yield response to Folicur.
- Further work must investigate how much of the N that is mineralised after February is taken up by the crop.
- The results from this project have been used to develop the 'N-Calc' fertiliser recommendation system run by Growhow UK Ltd and to help to revise the relationship between N rate and potential yield in the new RB209 guidelines.