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Optimum N rate and timing for semi-dwarf oilseed rape

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CONTENTS

1. ABSTRACT

This project compared a semi-dwarf variety (PR45D03) with a standard height variety (Excalibur) to investigate whether:

i) a semi-dwarf variety has a different economically optimum nitrogen (N) rate and different optimum N timings,

ii) ‘Canopy Management’ principles apply for a semi-dwarf variety,

iii) there are any differences in the N residues following harvest, and

iv) a semi-dwarf responds differently to a PGR.

Three winter oilseed rape experiments were established in each of the 2008-09 and 2009-10 growing seasons near ADAS sites High Mowthorpe (N. Yorkshire), Rosemaund (Herefordshire) and Terrington (Norfolk). The hybrid varieties PR45D03 and Excalibur were tested at six or seven N rates applied at Conventional or Canopy Management timings, with or without Folicur.

Results showed that, despite being, on average, 33 cm shorter the semi-dwarf variety required the same amount of fertiliser N to achieve optimum yield. Several of the Canopy Management principles were shown to be the same for the semi-dwarf and standard height varieties including; a crop N uptake of 50 kg N/ha to build each unit of green area index (GAI), a similar target optimum GAI at flowering and the same N uptake efficiencies. Shorter stems did not affect the amount of N required to build each unit of GAI because lower stem biomass at flowering was compensated by a greater concentration of N in the stem.

The semi-dwarf variety produced similar sized yields to Excalibur, and by harvest there were no significant differences in the amount of N taken up by the crop and the amount of N taken off in the seed between the variety types. The semi-dwarf variety had an average stem biomass of 3.75 t/ha compared with 4.52 t/ha for Excalibur, and a greater N concentration in the stem and pod wall tissue at two sites. As a result of these counteracting effects both the semi-dwarf and standard height variety left a similar amount of N in crop residues following harvest.

In the one experiment where the canopy following winter exceeded the minimum threshold GAI for using a PGR it was shown that Folicur applied at 1.0 l/ha at the green bud stage significantly increased the yield of the semi-dwarf variety. This indicates that semi-dwarfs will respond positively to PGRs when canopies are large. Folicur was shown to increase seeds/m^2 by increasing the amount of light that penetrated through the flowering layer.

2. SUMMARY

2.1. Introduction

Good yields, along with less lodging, easy management and swifter harvesting, make semi-dwarf oilseed rape varieties an attractive option for many growers. The semi-dwarfs developed so far have been around 20 cm shorter than Castille which, in turn, is about 25 cm shorter than the tallest hybrid (Excel). It is not known whether semi-dwarfs have a different requirement for fertiliser N compared with taller varieties, nor is it known whether the optimum N timings are different. However, two alternative hypotheses may be proposed: 1) the lower lodging risk of semi-dwarfs means that yields continue to respond to greater amounts of N, resulting in a greater economic optimum N rate; or 2) potentially lower stem biomass means that less N is required for supporting tissue, thereby reducing the N optima.

It is also unknown as to whether semi-dwarf varieties will benefit from the application of ‘Canopy Management’ principles of N timings and rates that aim to achieve optimum sized canopies. These principles have been shown to increase yield over conventional practices in standard height varieties in situations where they would have produced an over-large canopy (Berry and Spink, 2009). Over-large canopies have been shown to both set fewer seeds/m^2 and to be more lodging prone. In a recent study (Sustainable Arable LINK project LK0979), a semi-dwarf variety had a similar green area index in early spring to standard height varieties, indicating that this variety type may have a similar potential for producing over-large canopies by flowering.

This project aims to understand the physiological basis that determines whether semi-dwarf varieties have a different optimum rate and timing of N fertiliser. This will be used to understand whether the Canopy Management principals can be used with semi-dwarfs. The N use efficiency of a semi-dwarf is also compared with a standard height variety and also whether a different amount of N is returned to the soil (due to fewer crop residues). The latter will be important for determining whether the N requirement of following crops is different after a semi-dwarf oilseed rape crop.

2.1.1. Aim and objectives

Project Aim

Investigate whether semi-dwarf oilseed rape has a different optimum N rate and N timing from standard height varieties.

Specific Objectives

1. Investigate whether semi-dwarf oilseed rape has a different optimum N rate and N timing.
2. Understand whether the Canopy Management principals can be applied to Semi-dwarf varieties.
3. Quantify the N use efficiency of semi-dwarfs and whether they leave different amounts of N in crop residues for following crops.
4. Assess the response of the semi-dwarf variety to the growth regulatory effects of Folicur and any interactions with N management.

2.2. Materials and methods

2.2.1. 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 amounts 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 green bud stage (GS3,3 to 3,5) when the stems were just starting to extend. This usually occurred in late March or 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, equivalent to 60 kg N/ha for each tonne above 3.5 t/ha.

2.2.2. Field experiments

Sites

Experiments were carried out in 2008/9 and 2009/10. Experiments were drilled near ADAS Terrington in Norfolk (silty clay loam), near ADAS High Mowthorpe in 2008/09 (Shallow silty clay loam over chalk) or Thorneholme in 2009/10 (silty clay loam) both in E. Yorkshire and near ADAS Rosemaund in Herefordshire (sandy clay loam).

Experimental factors and design

Four factors were investigated: variety, N rate, N timing and a growth regulatory fungicide Folicur. At each site, within each of four replicates, variety formed main plots in which the N rate and N timing were randomised. At each site Folicur was then applied across one half of each block. The position of the Folicur strip was randomised for each block. This type of design is a special case of a split plot design where the sub-plot treatments are not randomised separately for each whole plot, but are randomly allocated to strips of subplots across each block. This is usually called a strip design or a criss-cross design. Each plot measured 18 m by 3.5 m.

The two varieties used were the standard height variety Excalibur and the semi-dwarf variety PR45D03, each drilled at 70 seeds/m^2. In 2008/9 seven N rates were used (0, 60, 120, 180, 240, 300, 360 kg/ha) and in 2009/10 six N rates were used which differed with site: 0, 60, 120, 180, 240 and 300 kg/ha at Thornholme and Rosemaund, and 0, 70, 140, 210, 280 and 350 at Terrington. All N was applied by hand as ammonium nitrate (34.5% N). All N rates, apart from the nil, were applied at either Conventional or Canopy Managed timings. Conventional timings were for 50% of the N applied in late February/March and 50% applied at green bud (GS3,3 to 3,5) (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 (GS3,3 to 3,5) and the remaining N was applied between yellow bud and mid-flowering. The Folicur treatment was applied at late green bud (GS3,6). 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.

2.2.3. 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. Lodging was 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 measured. Oil content was measured in 2008/9.

2.2.4. Calculations and statistics

Analysis of variance procedures within Genstat 11 (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. The gross margin over N costs was calculated by assuming a seed yield price of £235/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%.

2.3. Results

As expected PR45D03 was significantly shorter than Excalibur, with height reductions ranging from 13 to 46 cm, and averaging 33 cm, across the six experimental sites. At 240 kg N/ha, the average height of Excalibur was 134 cm compared with 101 cm for PR45D03.

2.3.1. Economic optimum N rate

There were no differences detected in the economically optimum N rate between Excalibur and PR45D03, due to Canopy Management or due to Folicur in any of the experiments. This was despite differences in the components of yield (seed size and seeds/m^2) between the variety types. At Terrington and Rosemaund in 2008/9, PR45D03 produced significantly ($P<0.001$) more seeds than Excalibur (12% and 11% more seeds/m^2, respectively), and at all sites in 2008/9 and Thornholme in 2009/10 it had a significantly lower thousand seed weight, with reductions of 2.5% to 7.6% relative to Excalibur. The small seeds of PR45D03 indicate that higher yields could be achieved by providing better seed filling conditions. Seed yield (Summary Tables 1 and 2), total biomass and total N uptake for the two variety types were similar and it is likely that these characteristics are more important for determining optimum N rate than differences in crop height.

2.3.2. Canopy management

In 2008/9, soil and crop N measured in February was low at all three sites (Summary Table 1). In 2009/10, although the canopies at all three sites were moderate to large before winter, they were reduced by the unusually cold winter weather. Consequently, the canopies measured in February were very small at Terrington and moderate at Thornholme and Rosemaund (Summary Table 2). Therefore, in all experiments the differences in N management between Conventional and Canopy Managed treatments were not as great as they have been in some previous experiments. When SNS is low, it is necessary to apply some early N for the Canopy Managed treatments to allow sufficient time for the crop to take up all the N required to build an optimum sized canopy. This means that the differences in N timing between the Canopy Managed treatments and the Conventionally managed treatments is smaller particularly at the lower N rate treatments.

In 2008/9 Canopy Management did not affect yield at any of the three sites (Summary Table 1). In February the canopies were small, and Canopy Management did not affect growth up to flowering. There was no evidence that over-large canopies were achieved at flowering with the Conventional N timings, with the largest canopy being at Rosemaund, with GAI 3.2. There were also no significant differences in light interception or reflection at flowering, between Canopy Managed and Conventional treatments in 2008/9. The observation that Canopy Management did not significantly reduce the yield of the semi-dwarf variety (Summary Table 1), even in crops with very small canopies, indicates that Canopy Management is appropriate for semi-dwarf varieties and may increase the yield of semi-dwarfs when canopies following winter are large.

In 2009/10, Canopy Management did not affect yield of either Excalibur or PR45D03 at any of the three sites (Summary Table 2). This season provided a robust test for the Canopy Management approach because the uptake of later Canopy Management N applications were delayed by the dry spring and the third N application was applied later than planned at Thornholme. N uptake by OSR crops has been shown to slow after flowering therefore there is a risk associated with applying N too late. At Thornholme the 3rd N split was applied when PR45D03 was beginning to flower and Excalibur was in full flower. At Rosemaund the crop was less advanced when the 3rd split was applied, but the application was preceded by several days of dry weather and followed by a further two weeks without rain, so much of the applied N may not have been available to the crop until well into flowering. However, at both sites the differences in final crop N content between the N timing treatments were not significant, and there was evidence of continued N uptake after flowering of up to 58 kg/ha in the the higher N rates applied at Canopy Managed timings.

Summary Table 1. 2008/9 experiment summary.

	Terrington		Mowthorpe		Rosemaund	
Jan/Feb soil mineral N (kg/ha)	34		34		26	
Jan/Feb additionally available N (kg/ha)	17		75		26	
Jan/Feb crop N content (kg/ha)	12		3		22	
Jan/Feb GAI	0.25		0.09		0.57	
N timing strategy	Conv	CM	Conv	CM	Conv	CM
Optimum N rate (kg/ha)	253	253	244	244	209	209
N rate at 1st split (end Feb/early March)	126	60	122	60	104	60
N rate at 2nd split (early stem ext.)	125	155	122	184	105	149
N rate at 3rd split (yellow bud to mid flower)	0	38	0	0	0	0
Yield at opt N Excalibur (t/ha)	4.19	4.04	4.58	4.45	5.21	5.22
Yield at opt N Excalibur + Folicur (t/ha)	4.34	4.26	4.59	4.59	5.02	5.08
Yield at opt N PR45D03 (t/ha)	4.25	4.20	4.30	4.26	5.59	5.53
Yield at opt N PR45D03 + Folicur (t/ha)	4.34	4.34	4.28	4.27	5.04	5.05

Conv – conventional N timing strategy; CM – Canopy Managed N timing strategy.

Additionally available N (AAN) is an estimate of the amount of N that will become available for crop uptake through mineralisation between February and crop maturity.

Summary Table 2. 2009/10 experiment summary.

	Terrington		Thornholme		Rosemaund	
Jan/Feb soil mineral N (kg/ha)	18		38		14	
Jan/Feb additionally available N (kg/ha)	31		59		25	
Jan/Feb crop N content (kg/ha)	13		49		54	
Jan/Feb GAI	0.24		0.9		1.12	
N timing strategy	Conv	CM	Conv	CM	Conv	CM
Optimum N rate (kg/ha)	228	228	215	215	176	176
N rate at 1st split (end Feb/early March)	114	60	107	40	88	40
N rate at 2nd split (early stem ext.)	114	168	108	107	88	136
N rate at 3rd split (yellow bud to mid flower)	0	0	0	68	0	0
Yield at opt N Excalibur (t/ha)	3.47	3.47	4.98	4.85	4.78	4.98
Yield at opt N Excalibur + Folicur (t/ha)	3.73	3.70	5.20	5.17	5.54	5.61
Yield at opt N PR45D03 (t/ha)	3.50	3.64	5.00	5.07	4.89	4.78
Yield at opt N PR45D03 + Folicur (t/ha)	3.72	3.83	4.98	5.08	5.52	5.51

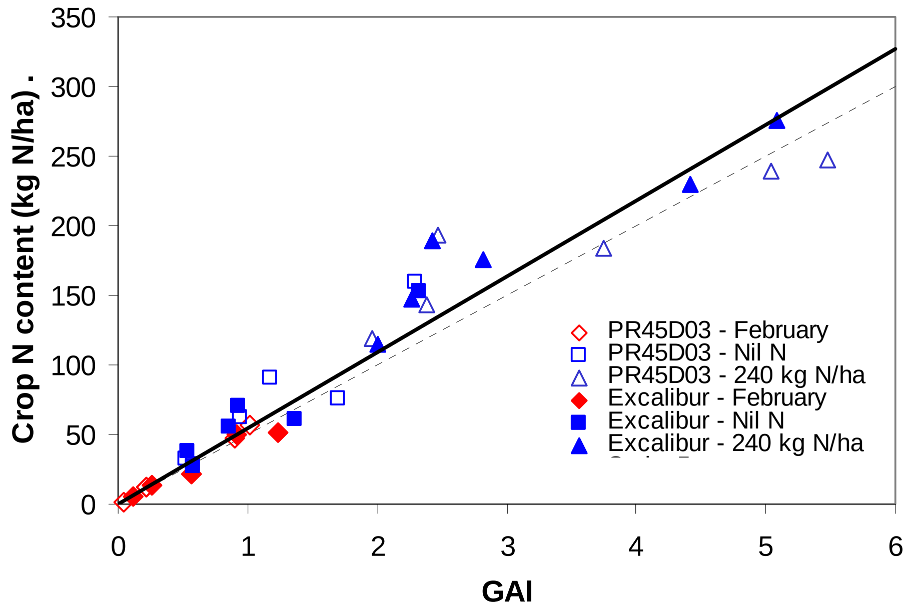
Conv – conventional N timing strategy; CM – Canopy Managed N timing strategy.

Additionally available N (AAN) is an estimate of the amount of N that will become available for crop uptake through mineralisation between February and crop maturity.

The only site at which over-large canopies were achieved at flowering in 2009/10 was Rosemaund, which averaged GAI 5.45 for the Conventional N timings (N rate 240 kg N/ha) compared to 4.70 for the Canopy Managed timings. Although the difference in GAI was not significant, Canopy Management did significantly reduce the amount of light intercepted by the flowers. This led to a small, but non-significant yield increase of 0.2 t/ha for Excalibur (Summary Table 2). At Thornholme there was a significant reduction in GAI and the amount of light intercepted and reflected by the canopy due to the Canopy Management strategy. These effects did not increase yield because the GAI for the Conventional N timings were less than the optimum. Importantly Canopy Management did not reduce yield. The small canopy at Terrington meant that the crop did not respond to Canopy Management.

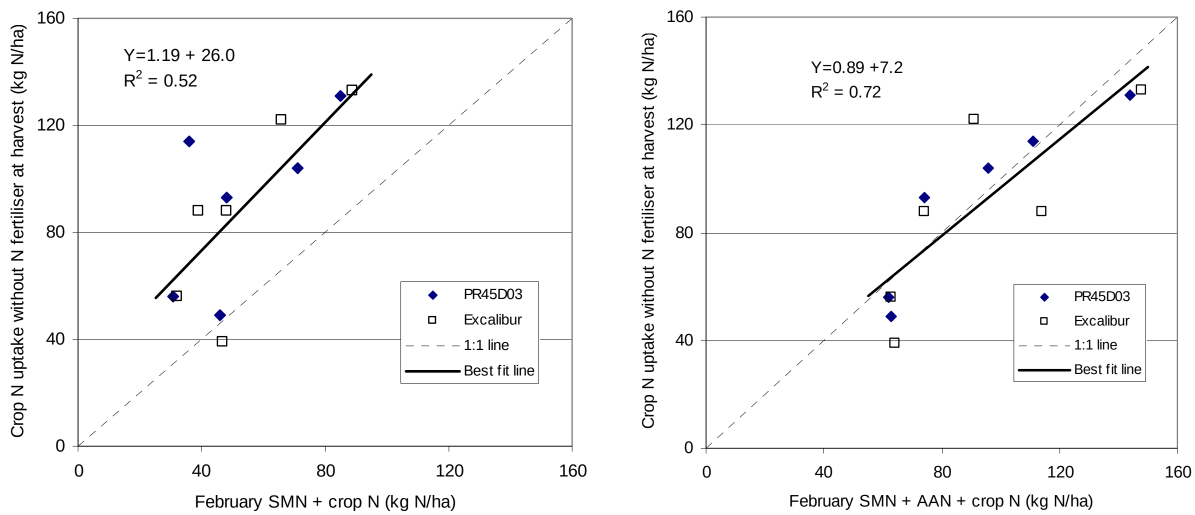
Several components of the Canopy Management principles developed by Berry and Spink (2009) and Lunn *et al.* (2001) and used in the GrowHow 'N-Calc' fertiliser recommendation system were shown to be applicable for semi-dwarf varieties as described below. The requirement for the crop to take up 50 kg N/ha to build each unit of GAI was shown to hold true for both standard height and semi-dwarf hybrids (Summary Figure 1). At flowering PR45D03 produced a larger GAI than Excalibur at two sites with no differences at the other four sites. PR45D03 intercepted more light than Excalibur at one site, with no difference at the other sites. The relatively small differences in GAI and light interception between the varieties indicates that the optimum GAI for intercepting the majority of incoming light will be the same for both varieties. Across the six sites there were no significant differences for the efficiency with which the two varieties took up the soil mineral N (SMN) that was measured in February or the applied fertiliser N. There was a strong positive relationship between the amount of N taken up by the crop in the absence of fertiliser and the amount of SMN and crop N measured in February (Summary Figure 2a). It was apparent that the unfertilised crops generally took up more N than the combined SMN plus crop N measured in February. On average the crops took up an additional 36 kg N/ha. Previous research has shown that the amount of N taken up by unfertilised crops was similar to the amount of SMN plus crop N (Berry and Spink, 2009). The difference between these two studies is likely to have been caused by the experimental sites in this current study having soils with a greater potential for mineralisation between February and crop maturity. When an estimate of the amount of mineralisation (referred to as additionally available N – AAN) was added to the February SMN and crop N, then the prediction of the amount of N taken up by the unfertilised crops was improved (Summary Figure 2b). The fertiliser uptake efficiency was calculated for the 240 kg N/ha fertiliser rate by dividing the difference in crop N uptake at crop maturity between the unfertilised crop and the crop fertilised at 240 kg N/ha by the fertiliser rate. This showed that across the six sites there was no significant difference in fertiliser uptake efficiency between the variety types and the average uptake efficiency was 47%. The fertiliser uptake efficiency was lower than found by Berry and Spink (2009) who estimated an average uptake efficiency of 57% at the N rates closest to the economic optimum N rate (average of 169 kg N/ha). There are two possible reasons for this difference; 1) in this study the N uptake efficiency was calculated for 240 kg N/ha which was, on average, 19 kg N/ha greater than the economic optimum N rate, and it is known that N uptake efficiency decreases at higher N rates, 2) the very dry spring in 2010 reduced N uptake efficiency. The average uptake efficiency in 2010 was 41% compared with 53% in 2009.

This report indicates that both the standard height and semi-dwarf variety types take up N with similar rates of efficiency, require the same amount of N to build each unit of GAI and have a similar optimum GAI target. This indicates that both variety types will require the same amount of fertiliser to achieve optimum GAI and supports the observation that there was no difference in the economic N rates between the variety types (Summary Tables 1 and 2).



Summary Figure 1. The relationship between Crop N content (kg N/ha) and Green Area Index (GAI) of varieties PR45D03 and Excalibur when measured in February and at mid flowering (Nil N and 240 kg N/ha) in the growing seasons 2008/9 and 2009/10. The bold line is the fitted relationship and the dotted line is the expected relationship (1 unit GAI = 50 kg N/ha).

(a) (b)

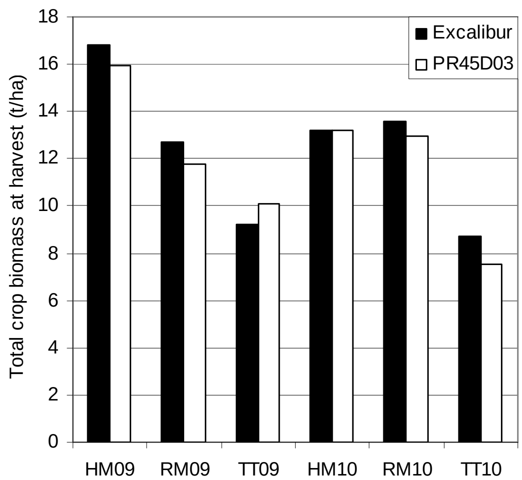


Summary Figure 2. Relationship between a) February SMN + crop N and the amount of N taken up by unfertilised crops by harvest and b) February SMN + additionally available N (due to mineralisation) + crop N and the amount of N taken up by unfertilised crops by harvest. Data from each of the 6 experiments carried out within the study.

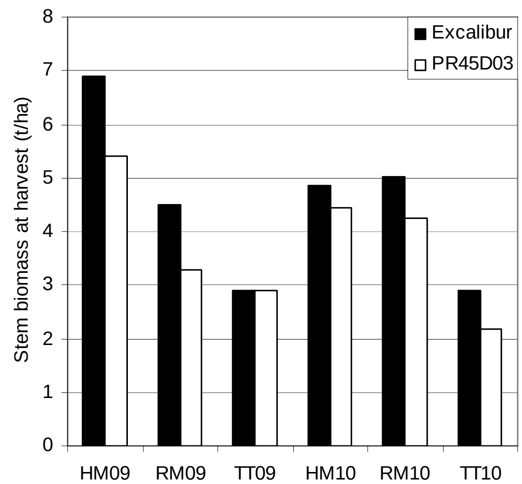
2.3.3. Crop biomass, N uptake and N residues following harvest

At harvest there was no significant difference in total crop biomass measured at 240 kg N/ha between Excalibur and PR45D03 at any of the sites (Summary Figure 3). Across all sites the average crop biomass for Excalibur was 12.4 t/ha compared with 11.9 t/ha for PR45D03. PR45D03 had an average stem biomass of 3.75 t/ha which was significantly less than Excalibur at 4.52 t/ha (Summary Figure 3b). The reduction in stem biomass was less than may have been expected given that the height of PR45D03 was on average 33 cm (25%) shorter. Longer branches from the bottom of the semi-dwarf main stems may have partially compensated for the shorter main stems. There was no significant difference in the biomass of the pod walls with both varieties averaging 4.01 t/ha across the six sites.

(a)



(b)



Summary Figure 3. a) Total biomass at harvest; b) stem biomass at harvest. All measurements for the 240 kg N/ha treatment without Folicur. HM – High Mowthorpe, RM – Rosemaund, TT – Terrington.

There was no difference between Excalibur and PR45D03 in the total amount of N taken up by the crop at harvest, with both varieties taking up on average 202 kg N/ha at a fertiliser rate of 240 kg N/ha across the six sites. PR45D03 took off 10 kg/ha less N in the seed at High Mowthorpe in 2008/9, but there were no variety differences in N offtake in the seed at any of the other five experiments. On average, both varieties took off 123 kg N/ha in the seed and both left a similar amount of N in the crop residues of approximately 75 kg N/ha. At two sites the stem and pod residues of PR45D03 had a significantly greater tissue N concentration than Exalibur which compensated for the lower stem biomass in terms of the N residues following harvest. These results indicate that the N residues following semi-dwarf oilseed rape are not different from those of standard height varieties.

2.3.4. Folicur

Effects of Folicur differed between the two seasons. In 2008/9 Folicur at 0.5 l/ha increased yield of both Excalibur and PR45D03, on average, by 0.15 t/ha at Terrington but did not affect yield at High Mowthorpe, and reduced the yield of PR45D03 by 0.51 t/ha and the yield of Excalibur by 0.16 t/ha at Rosemaund. In contrast, in 2009/10, Folicur application significantly increased yield at all three sites, by an average of 0.22 t/ha at Terrington, 0.67 t/ha at Rosemaund, and at Thornholme it increased the yield of Excalibur by 0.27 t/ha and had no effect on PR45D03. It should be recognised that all experimental sites, apart from Rosemaund in 2009/10, had a GAI in January/February of less than one (the threshold above which spring PGRs are normally recommended). In 2008/9 the average GAI in January/February across the three sites was 0.30 and in 2009/10 the average GAI was 0.75. The greater GAI in 2009/10 helps to explain the greater yield increases in this season. The yield responses to Folicur were not affected by the use of Canopy Managed N timings compared with Conventional N timings.

The greatest yield response to Folicur was at Rosemaund in 2009/10. This effect was likely to be because this site had the largest GAI in January/February (1.12) and at flowering (4.7 to 5.5) which was significanty above the optimum GAI required at flowering of 3.5. The significant yield increase for PR45D03 at this site indicates that semi-dwarfs will respond positively to PGRs when canopies are large. The most likely mechanism for the yield increases was the significant reduction in light reflection from the flowers that was caused by Folicur. This would have allowed more light to reach the photosynthetic tissues, thereby allowing more photosythesis during the critical period when the number of seeds were set. Folicur also reduced the amount of leaning at Rosemaund, particularly in Excalibur, although the relatively low levels of leaning which occurred were not likely to have influenced yield significantly. It is worth noting that this reduction in leaning occurred in the absence of any height response to Folicur, at Rosemaund or at the other sites in 2009/10, which indicates that Folicur may have reduced leaning by affecting the architecture of the canopy.

Disease was minimised in all experiments by using fungicides without PGR activity. However, it is impossible to rule out the possibility that part of the yield increases from Folicur were through improved disease control.

The yield reduction following Folicur application at Rosemaund in 2008/9, was likely to have occurred because even without the PGR the GAI at flowering was below the optimum for yield, and Folicur reduced this yet further causing a reduction in light interception by the green tissues during the seed setting period and consequently reduced yield. This hypothesis is supported by the observation that the reduction in yield was due to a reduction in seed number, rather than seed size. It should be noted that the GAI at the start of stem extension was 0.57 and PGRs would not normally be recommended for crops with a GAI of less than 1.

In five of the six experiments, Folicur treatment reduced the fraction of light intercepted by the flowers and/or reduced the amount of light reflected by the flowers of the standard height and semi-dwarf varieties. This shows that Folicur reduced the size of the flower layer, which for over-large canopies will help the crop set more seeds/m^2. This study has shown semi-dwarfs have the potential to produce over-large canopies which indicates that they will respond positively to PGRs in particular conditions.

2.4. Conclusions

- Across the six experiments the semi-dwarf variety PR45D03 had an avarge height of 101 cm compared with 134 cm for Excalibur.
- It was shown that Excalibur and PR45D03 had the same economic optimum N rates and produced similar yields.
- Canopy Management N timings gave the same yield as earlier Conventional N timings for the semi-dwarf and standard height varieties.
- Similar to standard height varieties, semi-dwarfs were shown to also have the potential to produce over-large canopies at flowering which would reduce the number of seeds set and yield potential. This indicates that Canopy Management N timings could increase the yield of semi-dwarfs when they have canopies following winter that are at risk to becoming over-large.
- It was shown that the Canopy Management principles used for standard height varieties also apply for semi-dwarf varieties. These include a similar soil and fertiliser uptake efficiency, the crop must take up 50 kg N/ha to build each unit of GAI and a similar optimum GAI at flowering.
- The experiments provided further evidence that the Canopy Management approach has been successfully adapted for crops with small canopies following winter, such that there is no yield penalty from delaying some of the N until yellow bud / early flowering.
- The semi-dwarf variety took up a similar amount of N and contained a similar amount of N in the seed to the standard height variety. There is therefore no evidence that the N residues remaining after harvest differ for semi-dwarfs.
- There was no difference in N use efficiency (kg of seed per kg of available soil and fertiliser N) between the semi-dwarf and standard height variety as both varieties yielded similarly at a range of N rates including the economic optimum rate.
- The prediction of the soil N supply (SNS) from the February soil mineral N plus crop N was improved by adding an estimate of the amount of N mineralised after February that would be available for crop uptake. This mineralisable fraction of soil N is known as the additionall available N (AAN).
- At harvest, the overall biomass of PR45D03 averaged 11.9 t/ha compared to 12.4 t/ha for Excalibur. This difference was not statistically significant.
- In the one experiment where an over-large canopy was produced it was shown that Folicur significantly increased the yield of the semi-dwarf variety, which indicates that semi-dwarfs will respond positively to PGRs when canopies are large.
- Folicur was shown to increase seeds/m^2 by increasing the amount of light that penetrated through the flowering layer.
- There may be an opportunity to maximise yields of PR45D03 by focusing on seed filling conditions. PR45D03 generally produced higher seed numbers than Excalibur, but lower seed weight.

3. TECHNICAL DETAIL

3.1. Introduction

Several breeding companies are developing semi-dwarf oilseed rape varieties and some of these have already featured on the HGCA Recommended Lists (RL). The yields of semi-dwarf varieties have been catching up the standard height variety yields and are now only slightly less and sometimes on a par. In the 2011/12 oilseed rape RL (East and West region) the highest yielding semi-dwarf cultivar (DK-Sequoia) had a yield of 101% of the control varieties. This along with the perceived ease of harvesting makes semi-dwarf varieties an attractive option for many growers. The semi-dwarfs developed so far have been around 20 cm shorter than Castille which, in turn, is about 25 cm shorter than the tallest hybrid (Excel). It is not known whether semi-dwarfs have a different requirement for fertiliser N compared with taller varieties, nor is it known whether the optimum N timings are different.

Ongoing LINK project LK0979 ‘Breeding for a reduced N requirement in oilseed rape’ showed the semi-dwarf variety PR45D01 had a lower stem biomass than ‘standard’ height varieties at two out of four sites. This may indicate that the semi-dwarf variety has a lower requirement for N. On the other hand the semi-dwarfs have a lower lodging risk which may indicate that N can be pushed higher to increase yield.

Since 2005/6 HGCA and Growhow UK Ltd have been testing a ‘Canopy Management’ method of N timings which involves applying sufficient N to build a canopy size of 3.5 by flowering, then applying additional amounts of N at yellow bud or early flowering depending on the crop’s yield potential. Compared with a conventional approach of applying N before and during early stem extension, this approach has been shown to increase yield on crops with a large canopy coming out of the winter. The mechanism of yield increase has been shown to be reduced lodging and the production of an optimum sized canopy at flowering which allowed more light to penetrate through the flower layer to the photosynthetic tissue in order to stimulate greater seed set. Semi-dwarfs have a lower lodging risk which may indicate that they will not benefit from lodging reductions due to Canopy Management. However, LINK project LK0979 showed that the semi-dwarf PR45D01 had a similar sized canopy in early spring to ‘standard height’ varieties. This may indicate that the semi-dwarfs are just as prone as other varieties to developing over-large canopies when crop management and environmental conditions are favourable for rapid growth, and may therefore benefit from Canopy Management timings. Research is also required to understand whether semi-dwarfs require 50 kg N/ha to build each unit of GAI the same as standard varieties and whether a GAI of 3.5 by flowering is optimal for light interception. It is possible that the shorter stem affects how much N is required to build each unit of GAI and the amount of light intercepted.

This project aims to understand the physiological basis that determines whether semi-dwarf varieties have a different optimum rate and timing of N fertiliser. This will be used to understand whether the Canopy Management principals can be used with semi-dwarfs. It will also help to predict the optimum N rate and timing for semi-dwarfs grown in different environments and for different types of semi-dwarfs when they enter the market (e.g. shorter dwarfs). The N use efficiency of semi-dwarfs is also compared with standard height varieties and also whether a different amount of N is returned to the soil (due to fewer crop residues). The latter will be important for determining whether the N requirement of following crops is different after a semi-dwarf oilseed rape crop.

3.1.1. Aim and objectives

Project Aim

Investigate whether semi-dwarf oilseed rape has a different optimum N rate and N timing from standard height varieties.

Specific Objectives

1. Investigate whether semi-dwarf oilseed rape has a different optimum N rate and N timing.
2. Understand whether the Canopy Management principals can be applied to semi-dwarf varieties.
3. Quantify the N use efficiency of semi-dwarfs and whether they leave different amounts of N in crop residues for following crops.
4. Assess the response of the semi-dwarf variety to the growth regulatory effects of Folicur and any interactions with N management.

3.2. Experimental design, materials and methods

3.2.1. Canopy Management approach

Previous work has demonstrated that oilseed rape must achieve an optimum green area index (GAI) of 3.5 units at flowering (Lunn *et al*., 2001). Larger canopies set fewer seeds/m^2 and are more prone to lodging, whilst smaller canopies do not intercept all of the available light. It has been shown that the crop must take up 50 kg N/ha to build each unit of GAI (Lunn *et al*., 2001), which means that the crop must take up 175 kg N/ha to achieve the optimum GAI of 3.5. It was assumed that any N that the crop had taken up by the end of winter remained in the crop until flowering and therefore contributed to the production of the optimum GAI. It was assumed that oilseed rape took up 100% of the soil mineral N measured in the soil in January/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 was assumed to be 3 kg N per day (Schjoerring *et al*., 1995). 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 in order to minimise the chance of producing an over-large canopy at flowering.

In late January or 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. 125 kg of fertiliser N must be applied to make up this shortfall assuming 60% of the fertiliser N applied is taken up by the crop.

The amount of fertiliser N required to achieve the optimum sized canopy was applied at the 2nd conventional split timing at green bud stage (GS3,3 to 3,5) when the stems were just starting to extend. This usually occurred in late March or early April. A small proportion of the N was applied at the 1st conventional split timing (late February/early March) if it was calculated that there would be insufficient time 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 made at the 2nd conventional split timing. Additional N for high yield potential was applied at yellow bud to mid flowering, equivalent to 60 kg N/ha for each tonne above 3.5 t/ha.

3.2.2. Field experiments

Sites

Experiments were carried out in 2008/9 and 2009/10. Experiments were drilled near ADAS Terrington in Norfolk (silty clay loam), near ADAS High Mowthorpe in 2008/09 (Shallow silty clay loam over chalk) or Thorneholme in 2009/10 (silty clay loam) both in E. Yorkshire and near ADAS Rosemaund in Herefordshire (sandy clay loam).

Experimental factors and design

Four factors were investigated: variety, N rate, N timing and a growth regulatory fungicide Folicur. At each site, within each of four replicates, variety formed main plots in which the N rate and N timing were randomised. At each site Folicur was then applied across one half of each block. The position of the Folicur strip was randomised for each block. This type of design is a special case of a split plot design where the sub-plot treatments are not randomised separately for each whole plot, but are randomly allocated to strips of subplots across each block. This is usually called a strip design or a criss-cross design. Each plot measured 18 m by 3.5 m.

The two varieties used were the standard height variety Excalibur and the semi-dwarf variety PR45D03. In 2008/9 seven N rates were used (0, 60, 120, 180, 240, 300, 360 kg/ha) and in 2009/10 six N rates were used which differed with site: 0, 60, 120, 180, 240 and 300 kg/ha at Thornholme and Rosemaund, and 0, 70, 140, 210, 280 and 350 at Terrington. All N was applied as ammonium nitrate (34.5% N). All N rates, apart from the nil, were applied at either conventional or Canopy Managed timings. Conventional timings were for 50% of the N applied in late February/March and 50% applied at green bud (GS3,3 to 3,5) at around 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.

Husbandry

All crops were sown at 70 seeds/m^2. 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 to the conventional N treatments. Fungicides without growth regulatory activity were used to minimise disease and to help ensure that any effects of the Folicur treatment resulted from growth regulation rather than disease control. Pests were minimised using molluscicides and insecticides. Desiccants were not used. See appendices 1 and 2 for further site details.

3.2.3. 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. Lodging was assessed at regular intervals. Many of the physiological measurements were carried out on a subset of the treatments. Yield was determined for all treatments using a small plot combine from an area of at least $30m^2$ and the moisture content measured. Oil content was measured in 2008/9.

3.2.4. Calculations and Statistics

Analysis of variance procedures within Genstat 11 (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 for each treatment of the form:

$$Y = A + BR^N + CN \qquad \text{Equation 1}$$

where *Y* is the seed yield (t/ha), *A, B, C* and *R* are constants. Each linear plus exponential function was fitted using a stepwise process within Genstat 11 involving the following steps: i) fitting a common curve to all fungicide treatments, ii) fitting separate parallel curves for each fungicide treatment, iii) fitting separate curves for each fungicide treatment by allowing parameters *A*, *B* and *C* all to vary, and iv) fitting separate curves for each fungicide treatments by allowing all parameters to vary. The sums of squares explained at each stage was calculated, and a test was made of the improvement in fit over the previous model. If there was no significant improvement between two stages, then the previous model was taken as the best description of the data. In general, fitting at stage (ii) was most satisfactory and the economic N rate (N_{OPT}) was determined from the fitted linear plus exponential parameters as follows:

$$N_{OPT} = \frac{\left[\ln\left(k/1000 - C\right) - \ln\left(B\left(\ln R\right)\right)\right]}{\ln R} \qquad \text{Equation 2}$$

where *k* is the breakeven price ratio between fertiliser N (p/kg) and grain (p/kg). A breakeven ratio of 2.5 was used in this study because this is used as a standard for fertiliser recommendations (Anon., 2010). The yield at the optimum N rate (Y_{OPT}) was calculated from the fitted parameters using equation 1.

The gross margin over N costs was calculated by assuming a seed yield price of £235/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). In 2008/9, 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%. When the oil content was less than 40% the same formula was used to calculate the price penalty from the basic oilseed rape price of £235/t.

3.3. Results

3.3.1. Experiment Year 1 – 2008/9

Soil and crop N in February

Experiments were drilled near ADAS Terrington (Norfolk) on 30/09/08, near ADAS High Mowthorpe (N. Yorkshire) on 26/09/08 and near ADAS Rosemaund (Herefordshire) on 15/9/08. The soil mineral N and GAI of the experimental crops was measured in late January or early February. A summary of this information (Table 1) shows that the combined supply of N from the crop and soil in February was 46 kg N/ha at Terrington, 48 kg N/ha at Rosemaund and 37 kg N/ha at High Mowthorpe.

Table 1. Fertiliser requirement for canopy managed treatments

	Terrington	High Mowthorpe	Rosemaund
SMN (kg/ha)	34	34	26
AAN (kg/ha)	17	75	26
GAI	0.25	0.09	0.57
Crop N (kg/ha)	12	3	22
SNS (kg/ha)	46	37	48
Fert N for GAI 3.5	215 (60 at 1st split)	251 (60 at 1st split)	212 (60 at 1st split)

SMN – soil mineral nitrogen; AAN – Additionally available N through mineralisation after February; SNS – soil nitrogen supply - sum of SMN and crop N; GAI – green area index

N treatments

The amount of fertiliser N required to achieve the optimum GAI of 3.5 by flowering was calculated at 215 kg/ha at Terrington, 212 kg/ha at Rosemaund and 251 kg/ha at High Mowthorpe based on the measurements of soil and crop N. At all the sites it was estimated that the crop would not be able to take up all of the N required to acheve the optimum sized canopy by mid-flowering if the N applications were delayed until the 2nd conventional split timing (green bud - GS3,3 to 3,5). Therefore, 60 kg N/ha was applied at the 1st conventional split timing. After sufficient N had been applied to achieve the optimum GAI of 3.5 the remainder of the N was applied between yellow bud and early/mid flowering in late April/early May. The N applications in each split are described in Tables 2 to 4. The dates of the N applications and Folicur treatment are described in Table 5.

Table 2. Terrington N applications (kg/ha)

N treatment	Management	1st split	2nd split	3rd split	Total
1		0	0	0	0
2	Conventional	30	30	0	60
3	Conventional	60	60	0	120
4	Conventional	90	90	0	180
5	Conventional	120	120	0	240
6	Conventional	150	150	0	300
7	Conventional	180	180	0	360
8	Managed	60	0	0	60
9	Managed	60	60	0	120
10	Managed	60	120	0	180
11	Managed	60	150	30	240
12	Managed	60	150	90	300
13	Managed	60	150	150	360

Table 3. High Mowthorpe N applications (kg/ha)

N treatment	Management	1st split	2nd split	3rd split	Total
1		0	0	0	0
2	Conventional	30	30	0	60
3	Conventional	60	60	0	120
4	Conventional	90	90	0	180
5	Conventional	120	120	0	240
6	Conventional	150	150	0	300
7	Conventional	180	180	0	360
8	Managed	60	0	0	60
9	Managed	60	60	0	120
10	Managed	60	120	0	180
11	Managed	60	180	0	240
12	Managed	60	190	50	300
13	Managed	60	190	110	360

Table 4. Rosemaund N applications (kg/ha)

N treatment	Management	1st split	2nd split	3rd split	Total
1		0	0	0	0
2	Conventional	30	30	0	60
3	Conventional	60	60	0	120
4	Conventional	90	90	0	180
5	Conventional	120	120	0	240
6	Conventional	150	150	0	300
7	Conventional	180	180	0	360
8	Managed	60	0	0	60
9	Managed	60	60	0	120
10	Managed	60	120	0	180
11	Managed	60	150	30	240
12	Managed	60	150	90	300
13	Managed	60	150	150	360

Table 5. Timings of Nitrogen and Folicur treatments

	Terrington	High Mowthorpe	Rosemaund
1st N timing	09-11/03/09	11-12/03/09	25/02/09
2nd N timing	03/04/09	09/04/09	20/03/09
3rd N timing	15/04/09	12/05/09	08/04/09
Folicur timing	14/04/09 (0.5 l/ha)	23/04/09 (0.5 l/ha)	04/04/09 (0.5 l/ha)

Seed yield

At Terrington, nitrogen rate and Folicur treatment significantly affected yield, with Folicur application increasing yield by an average of 0.15 t/ha (Table 6). Averaged over all treatments, yields significantly increased with each level of N from nil N (1.23 t/ha) to 180 kg N/ha (3.97 t/ha). Further increases were found up to 300 kg N/ha (4.26 t/ha), although these differences were not significant. There were no significant effects of variety or Canopy Management.

At High Mowthorpe, nitrogen rate and variety significantly affected yield, with Excalibur yielding on average 0.27 t/ha more than PR45D03 (Table 7). Averaged over all treatments, yields significantly increased with each level of N from nil N (2.11 t/ha) to 300 kg N/ha (4.57 t/ha). There was also a significant interaction between variety and nitrogen rate, with PR45D03 needing more N to reach its maximum yield. There were no significant effects of Folicur or Canopy Management.

At Rosemaund, nitrogen rate, variety and Folicur treatment significantly affected yield. The Folicur and variety treatments interacted such that Folicur significantly reduced the yield of PR45D03 by 0.51 t/ha and the yield of Excalibur by 0.16 t/ha (Table 8). Unlike at High Mowthorpe, PR45D03 was the higher yielding variety, yielding on average 0.17 t/ha more than Excalibur. Averaged over all treatments, yields significantly increased with each level of N from nil N (2.68 t/ha) to 180 kg N/ha (5.08 t/ha). There were no significant effects of Canopy Management.

Table 6. Terrington seed yields (t/ha @ 9% mc)

Variety	N rate kg/ha	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
		Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	0	0.95		0.95	1.37		1.37	1.16		1.16
Excalibur	60	2.23	2.05	2.14	2.65	2.27	2.46	2.44	2.16	2.30
Excalibur	120	3.21	3.10	3.15	3.40	3.22	3.31	3.31	3.16	3.23
Excalibur	180	4.02	3.82	3.92	3.95	4.19	4.07	3.99	4.00	4.00
Excalibur	240	4.08	3.93	4.00	4.15	4.19	4.17	4.11	4.06	4.09
Excalibur	300	4.12	4.33	4.22	4.28	4.16	4.22	4.20	4.24	4.22
Excalibur	360	4.53	3.93	4.23	4.42	4.22	4.32	4.48	4.07	4.28
Excalibur	Mean	3.31	3.16	3.23	3.46	3.37	3.42	3.38	3.27	3.32
PR45D03	0	1.37		1.37	1.24		1.24	1.30		1.30
PR45D03	60	2.46	2.06	2.26	2.36	2.79	2.58	2.41	2.42	2.42
PR45D03	120	3.32	3.49	3.41	3.44	3.22	3.33	3.38	3.36	3.37
PR45D03	180	3.87	3.72	3.79	4.05	4.13	4.09	3.96	3.92	3.94
PR45D03	240	4.14	4.27	4.21	4.31	4.20	4.26	4.22	4.24	4.23
PR45D03	300	4.24	4.22	4.23	4.26	4.43	4.35	4.25	4.32	4.29
PR45D03	360	4.16	4.06	4.11	4.54	4.20	4.37	4.35	4.13	4.24
PR45D03	Mean	3.37	3.31	3.34	3.46	3.46	3.46	3.41	3.39	3.40
Exc+D03	0	1.16		1.16	1.30		1.30	1.23		1.23
Exc+D03	60	2.35	2.05	2.20	2.50	2.53	2.52	2.43	2.29	2.36
Exc+D03	120	3.27	3.30	3.28	3.42	3.22	3.32	3.34	3.26	3.30
Exc+D03	180	3.95	3.77	3.86	4.00	4.16	4.08	3.97	3.96	3.97
Exc+D03	240	4.11	4.10	4.10	4.23	4.20	4.21	4.17	4.15	4.16
Exc+D03	300	4.18	4.27	4.23	4.27	4.29	4.28	4.23	4.28	4.26
Exc+D03	360	4.35	3.99	4.17	4.48	4.21	4.35	4.42	4.10	4.26
Exc+D03	Mean	3.34	3.23	3.29	3.46	3.42	3.44	3.40	3.33	3.36

Treatment	df	SED	F pr.
Folicur	165	0.0540	0.006
Variety	165	0.0540	0.167
N management	165	0.0540	0.182
N rate	165	0.1010	<0.001
Fol x Var	165	0.0763	0.527
Fol x Man	165	0.0763	0.575
Var x Man	165	0.0763	0.400
Fol x Nrate	165	0.1428	0.834
Var x Nrate	165	0.1428	0.904
Man x Nrate	165	0.1428	0.615
Fol x Var x Man	165	0.1080	0.966
Fol x Var x Nrate	165	0.2020	0.559
Fol x Man x Nrate	165	0.2020	0.783
Var x Man x Nrate	165	0.2020	0.985
Fol x Var x Man x Nrate	165	0.2856	0.402

Table 7. High Mowthorpe seed yields (t/ha @ 9% mc)

Variety	N rate kg/ha	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
		Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	0	2.23		2.23	2.24		2.24	2.24		2.24
Excalibur	60	3.14	3.20	3.17	3.50	3.31	3.40	3.32	3.25	3.29
Excalibur	120	3.79	3.97	3.88	3.73	3.86	3.80	3.76	3.92	3.84
Excalibur	180	4.38	4.40	4.39	4.34	4.31	4.33	4.36	4.36	4.36
Excalibur	240	4.30	4.67	4.48	4.74	4.70	4.72	4.52	4.69	4.60
Excalibur	300	4.58	4.58	4.58	4.72	4.73	4.72	4.65	4.65	4.65
Excalibur	360	4.48	4.73	4.60	4.63	4.72	4.67	4.55	4.72	4.64
Excalibur	Mean	3.84	3.97	3.91	3.98	3.98	3.98	3.91	3.97	3.94
PR45D03	0	1.94		1.94	2.04		2.04	1.99		1.99
PR45D03	60	3.03	3.00	3.02	2.84	2.86	2.85	2.93	2.93	2.93
PR45D03	120	3.52	3.85	3.69	3.59	3.64	3.61	3.55	3.74	3.65
PR45D03	180	3.96	4.07	4.02	3.87	4.04	3.95	3.91	4.06	3.98
PR45D03	240	4.13	4.09	4.11	4.19	4.11	4.15	4.16	4.10	4.13
PR45D03	300	4.49	4.44	4.47	4.53	4.53	4.53	4.51	4.48	4.50
PR45D03	360	4.45	4.43	4.44	4.57	4.47	4.52	4.51	4.45	4.48
PR45D03	Mean	3.65	3.69	3.67	3.66	3.67	3.67	3.65	3.68	3.67
Exc+D03	0	2.09		2.09	2.14		2.14	2.11		2.11
Exc+D03	60	3.09	3.10	3.09	3.17	3.08	3.12	3.13	3.09	3.11
Exc+D03	120	3.66	3.91	3.78	3.66	3.75	3.71	3.66	3.83	3.74
Exc+D03	180	4.17	4.24	4.20	4.10	4.18	4.14	4.14	4.21	4.17
Exc+D03	240	4.22	4.38	4.30	4.46	4.41	4.44	4.34	4.39	4.37
Exc+D03	300	4.54	4.51	4.52	4.62	4.63	4.63	4.58	4.57	4.57
Exc+D03	360	4.47	4.58	4.52	4.60	4.60	4.60	4.53	4.59	4.56
Exc+D03	Mean	3.75	3.83	3.79	3.82	3.83	3.82	3.78	3.83	3.81

Treatment	df	SED	F pr.
Folicur	165	0.0289	0.203
Variety	165	0.0289	<0.001
N management	165	0.0289	0.135
N rate	165	0.0540	<0.001
Fol x Var	165	0.0408	0.169
Fol x Man	165	0.0408	0.170
Var x Man	165	0.0408	0.548
Fol x Nrate	165	0.0764	0.355
Var x Nrate	165	0.0764	0.020
Man x Nrate	165	0.0764	0.560
Fol x Var x Man	165	0.0578	0.421
Fol x Var x Nrate	165	0.1080	0.292
Fol x Man x Nrate	165	0.1080	0.879
Var x Man x Nrate	165	0.1080	0.509
Fol x Var x Man x Nrate	165	0.1528	0.862

Table 8. Rosemaund seed yields (t/ha @ 9% mc)

Variety	N rate kg/ha	No Folicur Conv	No Folicur CM	No Folicur Mean	Folicur 0.5 l/ha) Conv	Folicur 0.5 l/ha) CM	Folicur 0.5 l/ha) Mean	Conv Mean	CM Mean	Grand Mean
Excalibur	0	2.76		2.76	2.60		2.60	2.68		2.68
Excalibur	60	4.06	3.87	3.96	3.80	3.92	3.86	3.93	3.90	3.91
Excalibur	120	4.86	4.84	4.85	4.56	4.46	4.51	4.71	4.65	4.68
Excalibur	180	5.13	5.19	5.16	4.93	5.06	4.99	5.03	5.13	5.08
Excalibur	240	5.16	5.19	5.17	5.12	5.17	5.15	5.14	5.18	5.16
Excalibur	300	5.28	5.33	5.31	5.22	5.31	5.26	5.25	5.32	5.28
Excalibur	360	5.39	5.57	5.48	5.10	5.26	5.18	5.25	5.41	5.33
Excalibur	Mean	4.66	4.68	4.67	4.47	4.54	4.51	4.57	4.61	4.59
PR45D03	0	3.03		3.03	2.61		2.61	2.82		2.82
PR45D03	60	4.64	4.31	4.47	3.83	3.88	3.85	4.23	4.09	4.16
PR45D03	120	5.02	4.97	5.00	4.57	4.74	4.66	4.80	4.85	4.83
PR45D03	180	5.51	5.51	5.51	4.96	4.95	4.96	5.24	5.23	5.23
PR45D03	240	5.58	5.47	5.53	5.11	5.17	5.14	5.34	5.32	5.33
PR45D03	300	5.82	5.77	5.80	5.17	5.16	5.17	5.50	5.47	5.48
PR45D03	360	5.74	5.84	5.79	5.25	5.06	5.15	5.50	5.45	5.47
PR45D03	Mean	5.05	4.99	5.02	4.50	4.51	4.50	4.77	4.75	4.76
Exc+D03	0	2.90		2.90	2.60		2.60	2.75		2.75
Exc+D03	60	4.35	4.09	4.22	3.81	3.90	3.86	4.08	3.99	4.04
Exc+D03	120	4.94	4.91	4.92	4.57	4.60	4.58	4.75	4.75	4.75
Exc+D03	180	5.32	5.35	5.33	4.95	5.00	4.97	5.13	5.18	5.15
Exc+D03	240	5.37	5.33	5.35	5.11	5.17	5.14	5.24	5.25	5.25
Exc+D03	300	5.55	5.55	5.55	5.19	5.24	5.21	5.37	5.40	5.38
Exc+D03	360	5.57	5.70	5.64	5.18	5.16	5.17	5.37	5.43	5.40
Exc+D03	Mean	4.86	4.83	4.84	4.49	4.52	4.51	4.67	4.68	4.68

Treatment	df	SED	F pr.
Folicur	165	0.0570	<0.001
Variety	165	0.0570	0.003
N management	165	0.0570	0.901
N rate	165	0.1067	<0.001
Fol x Var	165	0.0806	0.003
Fol x Man	165	0.0806	0.595
Var x Man	165	0.0806	0.556
Fol x Nrate	165	0.1509	0.951
Var x Nrate	165	0.1509	0.998
Man x Nrate	165	0.1509	0.997
Fol x Var x Man	165	0.1141	0.924
Fol x Var x Nrate	165	0.2134	0.880
Fol x Man x Nrate	165	0.2134	0.959
Var x Man x Nrate	165	0.2134	0.994
Fol x Var x Man x Nrate	165	0.3018	0.997

Oil content

At Terrington, oil content significantly decreased with increasing N rate (Table 9). Linear regressions showed a significant 0.77% decrease in oil content with every 100kg increase in N rate. Folicur did not affect oil content (Table 10), nor were there any significant interactions between Folicur and any other factor.

At High Mowthorpe, oil content significantly decreased with increasing N rate (Table 11). Linear regressions showed a significant 0.86% decrease in oil content with every 100kg increase in N rate. Folicur did not affect oil content (Table 12), nor were there any significant interactions between Folicur and any other factor.

At Rosemaund, oil content significantly decreased with increasing N rate (Table 13). Linear regressions showed a significant 0.87% decrease in oil content with every 100kg increase in N rate. Folicur did not affect oil content (Table 14), nor were there any significant interactions between Folicur and any other factor.

Table 9. Terrington oil contents (100% dry matter)

N rate	Excalibur			PR45D03			Conv	CM	Grand
kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
0	47.0		47.0	48.1		48.1	47.6		47.6
120	48.7	46.9	47.8	47.8	47.2	47.5	48.3	47.1	47.7
240	45.5	46.1	45.8	45.7	45.7	45.7	45.6	45.9	45.7
360	45.7	45.1	45.4	44.8	44.9	44.9	45.3	45.0	45.1
Mean	46.7	46.3	46.5	46.6	46.5	46.5	46.7	46.4	46.5

Treatment	df	SED	F pr.
Variety	45	0.274	0.794
N management	45	0.274	0.285
N rate	45	0.388	<0.001
Variety x Management	45	0.388	0.579
Variety x N rate	45	0.548	0.155
Management x N rate	45	0.548	0.268
Var x Man x Nrate	45	0.775	0.675

Without Folicur

Table 10. Terrington Oil contents (100% dry matter) effects of Folicur

	N rate	Conventional		Managed timing		Mean	
	kg/ha	Nil	Folicur	Nil	Folicur	Nil	Folicur
Excalibur	120	48.7	47.7	46.9	47.5	47.8	47.6
Excalibur	240	45.5	46.7	46.1	46.0	45.8	46.4
PR45D03	120	47.8	48.0	47.2	47.7	47.5	47.8
PR45D03	240	45.7	46.2	45.7	45.9	45.7	46.0
Mean		46.9	47.1	46.5	46.8	46.7	46.9

	df	SED	F pr.
Folicur	45	0.231	0.292
Variety	45	0.231	0.620
Management	45	0.231	0.088
N rate	45	0.231	<0.001
Fol x Var	45	0.327	0.799
Fol x Man	45	0.327	0.840
Var x Man	45	0.327	0.639
Fol x Nrate	45	0.327	0.357
Var x Nrate	45	0.327	0.678
Man x Nrate	45	0.327	0.197
Fol x Var x Man	45	0.463	0.904
Fol x Var x Nrate	45	0.463	0.371
Fol x Man x Nrate	45	0.463	0.067
Var x Man x Nrate	45	0.463	0.462
Fol x Var x Man x Nrate	45	0.655	0.236

Table 11. High Mowthorpe oil contents (100% dry matter)

N rate	Excalibur			PR45D03			Conv	CM	Grand
kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
0	45.9		45.9	45.3		45.3	45.6		45.6
120	45.9	45.7	45.8	45.9	46.6	46.2	45.9	46.1	46.0
240	42.1	43.6	42.9	45.3	44.6	45.0	43.7	44.1	43.9
360	43.0	42.1	42.6	43.2	42.9	43.1	43.1	42.5	42.8
Mean	44.2	44.3	44.3	44.9	44.8	44.9	44.6	44.6	44.6

Treatment	df	SED	F pr.
Variety	45	0.317	0.063
N management	45	0.317	0.984
N rate	45	0.449	<0.001
Variety x Management	45	0.449	0.799
Variety x N rate	45	0.635	0.036
Management x N rate	45	0.635	0.701
Var x Man x Nrate	45	0.898	0.297

Without Folicur

Table 12. High Mowthorpe oil contents (% dry matter) effects of Folicur

	N rate	Conventional		Managed timing		Mean	
	kg/ha	Nil	Folicur	Nil	Folicur	Nil	Folicur
Excalibur	120	45.9	45.5	45.7	45.2	45.8	45.3
Excalibur	240	42.1	42.9	43.6	42.6	42.9	42.7
PR45D03	120	45.9	45.4	46.6	45.8	46.2	45.6
PR45D03	240	45.3	44.4	44.6	43.3	45.0	43.8
Mean		44.8	44.6	45.1	44.2	45.0	44.4

	df	SED	F pr.
Folicur	45	0.424	0.175
Variety	45	0.424	0.027
Management	45	0.424	0.959
N rate	45	0.424	<0.001
Fol x Var	45	0.600	0.479
Fol x Man	45	0.600	0.435
Var x Man	45	0.600	0.698
Fol x Nrate	45	0.600	0.913
Var x Nrate	45	0.600	0.158
Man x Nrate	45	0.600	0.753
Fol x Var x Man	45	0.849	0.709
Fol x Var x Nrate	45	0.849	0.634
Fol x Man x Nrate	45	0.849	0.583
Var x Man x Nrate	45	0.849	0.189
Fol x Var x Man x Nrate	45	1.200	0.604

Table 13. Rosemaund oil contents (100% dry matter)

N rate	Excalibur			PR45D03			Conv	CM	Grand
kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
0	45.4		45.4	46.0		46.0	45.7		45.7
120	44.4	44.7	44.6	44.9	44.5	44.7	44.6	44.6	44.6
240	43.2	43.1	43.2	43.0	43.4	43.2	43.1	43.2	43.2
360	42.3	42.6	42.4	42.8	43.0	42.9	42.5	42.8	42.7
Mean	43.8	44.0	43.9	44.2	44.2	44.2	44.0	44.1	44.0

Treatment	df	SED	F pr.
Variety	45	0.211	0.170
N management	45	0.211	0.658
N rate	45	0.298	<0.001
Variety x Management	45	0.298	0.791
Variety x N rate	45	0.421	0.772
Management x N rate	45	0.421	0.963
Var x Man x Nrate	45	0.596	0.811

Without Folicur

Table 14. Rosemaund oil contents (100% dry matter) effects of Folicur

	N rate	Conventional		Managed timing		Mean	
	kg/ha	Nil	Folicur	Nil	Folicur	Nil	Folicur
Excalibur	120	44.4	45.1	44.7	45.2	44.6	45.2
Excalibur	240	43.2	43.1	43.1	43.1	43.2	43.1
PR45D03	120	44.9	44.3	44.5	44.3	44.7	44.3
PR45D03	240	43.0	43.1	43.4	42.9	43.2	43.0
Mean		43.9	43.9	43.9	43.9	43.9	43.9

	df	SED	F pr.
Folicur	45	0.1958	0.949
Variety	45	0.1958	0.298
Management	45	0.1958	0.975
N rate	45	0.1958	<0.001
Fol x Var	45	0.2769	0.158
Fol x Man	45	0.2769	0.824
Var x Man	45	0.2769	0.751
Fol x Nrate	45	0.2769	0.590
Var x Nrate	45	0.2769	0.343
Man x Nrate	45	0.2769	0.899
Fol x Var x Man	45	0.3915	1.000
Fol x Var x Nrate	45	0.3915	0.231
Fol x Man x Nrate	45	0.3915	0.703
Var x Man x Nrate	45	0.3915	0.467
Fol x Var x Man x Nrate	45	0.5537	0.467

Optimum N rates

At Terrington, regression analyses showed that fitting parallel curves for each treatment combination accounted for the most variation between N rate and yield (88.5%) although this was not a significant improvement on fitting one curve for all the data (P=0.056), so one curve was fitted to all treatments. The economically optimum N rate before taking account of oil premiums was 257 kg N/ha for all treatments and 253 kg N/ha after taking account of the oil content (Table 15).

At High Mowthorpe, regression analyses showed that fitting parallel curves for each treatment combination accounted for the most variation between N rate and yield (92.0%, P<0.001). The economically optimum N rate before taking account of oil premiums was 255 kg N/ha for all treatments and 244 kg N/ha after taking account of the oil content (Table 15).

At Rosemaund, regression analyses showed that fitting parallel curves for each treatment combination accounted for the most variation between N rate and yield (83.6%, P<0.001). The economically optimum N rate before taking account of oil premiums was 223 kg N/ha for all treatments and 209 kg N/ha after taking account of the oil content (Table 15).

Table 15. Optimum N rate and yields at N opt.

	Terrington	High Mowthorpe	Rosemaund
Economically optimum N rate (kg/ha)	253	244	209
Excalibur Conventional N timings	4.19	4.58	5.21
Excalibur Managed N timings	4.04	4.45	5.22
Excalibur Conventional N timings with Folicur	4.34	4.59	5.02
Excalibur Managed N timings with Folicur	4.26	4.59	5.08
PR45D03 Conventional N timings	4.25	4.30	5.59
PR45D03 Managed N timings	4.20	4.26	5.53
PR45D03 Conventional N timings with Folicur	4.34	4.28	5.04
PR45D03 Managed N timings with Folicur	4.34	4.27	5.05

Crop growth before stem extension

Crop assessments carried out in February before any N applications showed that the GAI, dry matter, N concentration and N content of the two varieties did not differ at Terrington or Rosemaund (Table 16). At High Mowthorpe, which had a much smaller crop than the other sites, Excalibur had significantly greater GAI, dry matter, N concentration and N content than the semi-dwarf PR45D03 (Table 16). Each unit of GAI contained 51.1 kg N/ha at Terrington, 42.0 kg N/ha at High Mowthorpe and 38.9 kg N/ha at Rosemaund. Previous studies have shown that oilseed rape crops contain about 50 kg N/ha per unit of GAI. However, it should be recognised that these N contents are for very small crops which is likely to increase the error associated with calculating the N content per unit GAI. There was no significant difference between the two varieties in crop kg N/ha per unit of GAI.

Table 16. February measurements.

Terrington

	GAI	Dry matter (t/ha)	N content (% of dry matter)	Crop N (kg/ha)
Excalibur	0.268	0.453	2.97	13.1
PR45D03	0.217	0.368	3.20	11.7
Mean	0.242	0.411	3.08	12.4
SED (df)	0.0765	0.1323	0.1476	3.99
F pr.	0.553	0.566	0.213	0.740

High Mowthorpe

	GAI	Dry matter (t/ha)	N content (% of dry matter)	Crop N (kg/ha)
Excalibur	0.119	0.115	4.35	4.99
PR45D03	0.044	0.046	4.04	1.88
Mean	0.082	0.080	4.19	3.43
SED (df)	0.0211	0.01574	0.0785	0.685
F pr.	0.038	0.023	0.031	0.020

Rosemaund

	GAI	Dry matter (t/ha)	N content (% of dry matter)	Crop N (kg/ha)
Excalibur	0.565	0.728	3.00	21.9
PR45D03	0.568	0.774	2.93	22.2
Mean	0.566	0.751	2.96	22.0
SED (df)	0.0348	0.774	0.1751	2.15
F pr.	0.952	0.446	0.697	0.914

GAI, dry weight and N content at mid-flowering

At all sites, increased N rates significantly increased the GAI of leaves and stems and the biomass and N content of all parts of the crop (Tables 17-25).

At Terrington, there were no significant effects of variety or Canopy Management on GAI (Table 17). The stem biomass data showed a significant interaction between variety and N rate; in nil N controls both varieties had very similar stem biomass, but at 240 kg N/ha Excalibur showed a much greater increase in stem biomass than PR45D03 (Table 18). The same trend was present for stem GAI, but the interaction was not significant.

The soil mineral N + crop N in February amounted to 46 kg N/ha at Terrington. In theory this would have been expected to be taken up into the crop by mid-flowering and to produce a GAI of 0.9 in control plots. The measurements at Nil N showed that the crop had taken up 27.8 kg N/ha (Table 23) and achieved a GAI of 0.58 (Table 17). It is possible that a low plant population meant that the roots had not grown to a sufficient density to take up all of the soil N by flowering, or some soil N may have been leached. Applying 240 kg N/ha would be expected to increase N uptake by 144 kg N/ha and increase the GAI by 2.9 units. The measured increases were 114 kg N/ha and 1.4 GAI units.

At High Mowthorpe, PR45D03 had significantly higher total GAI than Excalibur, due to higher leaf GAI rather than stem GAI (Table 19). The leaf and total GAI data also showed a significant interaction between variety and N rate; PR45D03 showed a greater increase in GAI with increased N rate than Excalibur. Leaf biomass showed the same effects, again with a significant interaction (Table 20). Variety did not have a significant effect on stem GAI, but did affect stem biomass. Excalibur had higher stem biomass than PR45D03 at both N levels, and showed a greater increase in stem biomass in response to higher N.

The soil mineral N + crop N in February amounted to 37 kg N/ha at High Mowthorpe. In theory this would have been expected to be taken up into the crop by mid-flowering and to produce a GAI of 0.7 in control plots. The measurements at Nil N showed that the crop had taken up 35 kg N/ha (Table 24) and achieved a GAI of 0.53 (Table 19). Applying 240 kg N/ha would be expected to increase N uptake by 132 kg N/ha and increase the GAI by 2.6 units. The measured increases were 145 kg N/ha and 2.8 GAI units.

At Rosemaund, as at High Mowthorpe, Excalibur showed higher stem biomass and greater N response in stem biomass than PR45D03 (Table 22), but there were no varietal differences in stem GAI. PR45D03 had significantly higher leaf biomass and GAI than Excalibur, and consequently a higher total GAI (Table 21).

The soil mineral N + crop N in February amounted to 48 kg N/ha at Rosemaund. In theory this would have been expected to be taken up into the crop by mid-flowering and to produce a GAI of 1.0 in control plots. The measurements at Nil N showed that the crop had taken up 68 kg N/ha (Table 25) and achieved a GAI of 1.53 (Table 21). Applying 120 kg N/ha would be expected to increase N uptake by 144 kg N/ha and increase the GAI by 2.9 units. The measured increases were 170 kg N/ha and 3.4 GAI units

Across all sites, a comparison of crop N content and GAI supported the ratio derived from previous work, that approximately 50 kg N/ha is required to build each unit of GAI. With the means of each variety-N rate combination from each site plotted together (Figure 1), the regression equation gave an actual value of 50.4 kg N/ha for each unit GAI. However, there were significant differences between the varieties in N content per unit GAI at both High Mowthorpe (P=0.026) and Rosemaund (P=0.032) (Tables 23-25). At both sites, PR45D03 used less N to build a unit of GAI or, since the N uptakes were more similar than GAIs, PR45D03 produced a greater GAI from the same amount of N uptake.

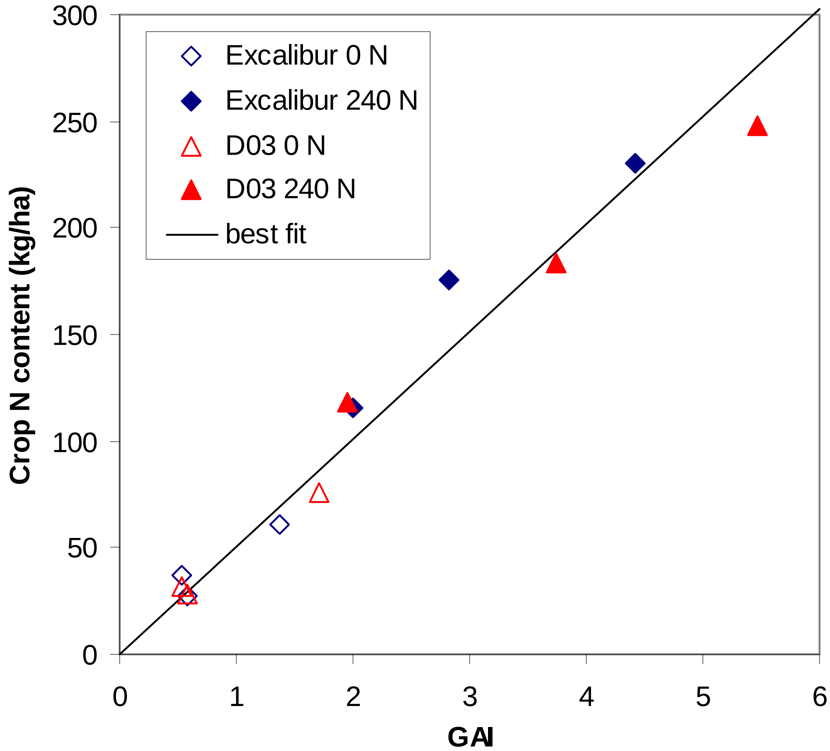


Figure 1. Comparison of GAI and crop N content, for all sites.

Table 17. Terrington. Mid flowering green area indices.

Variety	N rate kg/ha	GAI leaves Conv	CM	Mean	GAI stems Conv	CM	Mean	Total GAI Conv	CM	Mean
Excalibur	0	0.329		0.329	0.248		0.248	0.577		0.577
Excalibur	240	1.499	1.409	1.454	0.595	0.505	0.550	2.094	1.914	2.004
Excalibur	Mean	0.914	0.869	0.892	0.421	0.376	0.399	1.335	1.245	1.290
PR45D03	0	0.328		0.328	0.250		0.250	0.578		0.578
PR45D03	240	1.653	1.380	1.516	0.517	0.367	0.442	2.170	1.747	1.959
PR45D03	Mean	0.990	0.854	0.922	0.383	0.309	0.346	1.374	1.162	1.268
Exc+D03	0	0.329		0.329	0.249		0.249	0.577		0.577
Exc+D03	240	1.576	1.395	1.485	0.556	0.436	0.496	2.132	1.830	1.981
Exc+D03	Mean	0.952	0.862	0.907	0.402	0.342	0.372	1.355	1.204	1.279
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		21	0.1119	0.788	21	0.0377	0.177	21	0.1357	0.871
N management		21	0.1119	0.427	21	0.0377	0.127	21	0.1357	0.280
Nrate		21	0.1119	<0.001	21	0.0377	<0.001	21	0.1357	<0.001
Var x Man		21	0.1582	0.688	21	0.0533	0.695	21	0.1920	0.660
Var x Nrate		21	0.1582	0.777	21	0.0533	0.161	21	0.1920	0.869
Man x Nrate		21	0.1582	0.427	21	0.0533	0.127	21	0.1920	0.280
Var x Man x Nrate		21	0.2238	0.688	21	0.0754	0.695	21	0.2715	0.660

Table 18. Terrington. Mid flowering dry matter measurements.

Variety	N rate	Leaf biomass (t/ha)			Stem biomass (t/ha)			Flower biomass (t/ha)			Total biomass (t/ha)		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	0.330		0.330	1.207		1.207	0.216		0.216	1.753		1.753
Excalibur	240	1.075	1.032	1.054	2.574	2.422	2.498	0.563	0.544	0.553	4.212	3.997	4.104
Excalibur	Mean	0.703	0.681	0.692	1.890	1.814	1.852	0.389	0.380	0.384	2.982	2.875	2.928
PR45D03	0	0.300		0.300	1.206		1.206	0.318		0.318	1.825		1.825
PR45D03	240	1.503	0.979	1.241	2.143	1.501	1.822	0.722	0.545	0.634	4.369	3.025	3.697
PR45D03	Mean	0.902	0.640	0.771	1.675	1.354	1.514	0.520	0.432	0.476	3.097	2.425	2.761
Exc+D03	0	0.315		0.315	1.206		1.206	0.267		0.267	1.789		1.789
Exc+D03	240	1.289	1.005	1.147	2.359	1.961	2.160	0.642	0.544	0.593	4.290	3.511	3.901
Exc+D03	Mean	0.802	0.660	0.731	1.782	1.584	1.683	0.455	0.406	0.430	3.039	2.650	2.845
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		21	0.0897	0.390	21	0.1540	0.040	21	0.0506	0.084	21	0.274	0.548
N management		21	0.0897	0.129	21	0.1540	0.211	21	0.0506	0.342	21	0.274	0.170
Nrate		21	0.0897	<0.001	21	0.1540	<0.001	21	0.0506	<0.001	21	0.274	<0.001
Var x Man		21	0.1268	0.195	21	0.2178	0.435	21	0.0715	0.442	21	0.388	0.315
Var x Nrate		21	0.1268	0.240	21	0.2178	0.040	21	0.0715	0.829	21	0.388	0.392
Man x Nrate		21	0.1268	0.129	21	0.2178	0.211	21	0.0715	0.342	21	0.388	0.170
Var x Man x Nrate		21	0.1793	0.195	21	0.3080	0.435	21	0.1012	0.442	21	0.549	0.315

Table 19. High Mowthorpe. Mid flowering green area indices.

Variety	N rate kg/ha	GAI leaves Conv	CM	Mean	GAI stems Conv	CM	Mean	Total GAI Conv	CM	Mean
Excalibur	0	0.287		0.287	0.248		0.248	0.534		0.534
Excalibur	240	1.609	2.063	1.836	1.294	0.677	0.985	2.902	2.739	2.821
Excalibur	Mean	0.948	1.175	1.061	0.771	0.462	0.616	1.718	1.637	1.678
PR45D03	0	0.316		0.316	0.211		0.211	0.527		0.527
PR45D03	240	3.158	3.114	3.136	0.567	0.650	0.608	3.725	3.764	3.744
PR45D03	Mean	1.737	1.715	1.726	0.389	0.430	0.410	2.126	2.145	2.136
Exc+D03	0	0.301		0.301	0.229		0.229	0.531		0.531
Exc+D03	240	2.383	2.588	2.486	0.930	0.663	0.797	3.314	3.251	3.283
Exc+D03	Mean	1.342	1.445	1.394	0.580	0.446	0.513	1.922	1.891	1.907
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		14	0.1384	<0.001	14	0.1390	0.159	14	0.0799	<0.001
N management		14	0.1384	0.471	14	0.1390	0.353	14	0.0799	0.703
Nrate		14	0.1384	<0.001	14	0.1390	0.001	14	0.0799	<0.001
Var x Man		14	0.1958	0.383	14	0.1965	0.229	14	0.1130	0.540
Var x Nrate		14	0.1958	<0.001	14	0.1965	0.241	14	0.1130	<0.001
Man x Nrate		14	0.1958	0.471	14	0.1965	0.353	14	0.1130	0.703
Var x Man x Nrate		14	0.2769	0.383	14	0.2779	0.229	14	0.1598	0.540

Table 20. High Mowthorpe. Mid flowering dry matter measurements.

Variety	N rate	Leaf biomass (t/ha)			Stem biomass (t/ha)			Flower biomass (t/ha)			Total biomass (t/ha)		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	0.258		0.258	1.760		1.760	0.518		0.518	2.537		2.537
Excalibur	240	1.193	1.075	1.134	4.246	3.613	3.930	1.272	0.967	1.119	6.711	5.655	6.183
Excalibur	Mean	0.725	0.667	0.696	3.003	2.687	2.845	0.895	0.743	0.819	4.624	4.096	4.360
PR45D03	0	0.301		0.301	1.317		1.317	0.364		0.364	1.982		1.982
PR45D03	240	1.377	1.377	1.377	2.803	3.185	2.994	0.823	1.022	0.923	5.003	5.583	5.293
PR45D03	Mean	0.839	0.839	0.839	2.060	2.251	2.156	0.594	0.693	0.643	3.493	3.783	3.638
Exc+D03	0	0.280		0.280	1.539		1.539	0.441		0.441	2.259		2.259
Exc+D03	240	1.285	1.226	1.255	3.525	3.399	3.462	1.048	0.994	1.021	5.857	5.619	5.738
Exc+D03	Mean	0.782	0.753	0.767	2.532	2.469	2.500	0.744	0.718	0.731	4.058	3.939	3.999
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		14	0.0451	0.007	14	0.1122	<0.001	14	0.0617	0.013	14	0.1728	<0.001
N management		14	0.0451	0.525	14	0.1122	0.585	14	0.0617	0.670	14	0.1728	0.502
Nrate		14	0.0451	<0.001	14	0.1122	<0.001	14	0.0617	<0.001	14	0.1728	<0.001
Var x Man		14	0.0638	0.525	14	0.1587	0.040	14	0.0872	0.060	14	0.2444	0.033
Var x Nrate		14	0.0638	0.044	14	0.1587	0.046	14	0.0872	0.736	14	0.2444	0.349
Man x Nrate		14	0.0638	0.525	14	0.1587	0.585	14	0.0872	0.670	14	0.2444	0.502
Var x Man x Nrate		14	0.0903	0.525	14	0.2244	0.040	14	0.1233	0.060	14	0.3456	0.033

Table 21. Rosemaund. Mid flowering green area indices.

Variety	N rate kg/ha	GAI leaves Conv	CM	Mean	GAI stems Conv	CM	Mean	Total GAI Conv	CM	Mean
Excalibur	0	1.018		1.018	0.348		0.348	1.365		1.365
Excalibur	240	3.520	3.862	3.691	0.681	0.782	0.731	4.201	4.644	4.422
Excalibur	Mean	2.269	2.440	2.354	0.514	0.565	0.540	2.783	3.005	2.894
PR45D03	0	1.333		1.333	0.372		0.372	1.705		1.705
PR45D03	240	4.826	4.862	4.844	0.634	0.629	0.631	5.459	5.491	5.475
PR45D03	Mean	3.079	3.097	3.088	0.503	0.500	0.501	3.582	3.598	3.590
Exc+D03	0	1.175		1.175	0.360		0.360	1.535		1.535
Exc+D03	240	4.173	4.362	4.267	0.657	0.705	0.681	4.830	5.067	4.949
Exc+D03	Mean	2.674	2.769	2.721	0.509	0.533	0.521	3.183	3.301	3.242
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		21	0.1795	<0.001	21	0.0394	0.343	21	0.208	0.003
N management		21	0.1795	0.603	21	0.0394	0.549	21	0.208	0.575
Nrate		21	0.1795	<0.001	21	0.0394	<0.001	21	0.208	<0.001
Var x Man		21	0.2538	0.674	21	0.0557	0.511	21	0.295	0.627
Var x Nrate		21	0.2538	0.030	21	0.0557	0.130	21	0.295	0.102
Man x Nrate		21	0.2538	0.603	21	0.0557	0.549	21	0.295	0.575
Var x Man x Nrate		21	0.3589	0.674	21	0.0787	0.511	21	0.417	0.627

Table 22. Rosemaund. Mid flowering dry matter measurements.

Variety	N rate kg/ha	Leaf biomass (t/ha) Conv	CM	Mean	Stem biomass (t/ha) Conv	CM	Mean	Flower biomass (t/ha) Conv	CM	Mean	Total biomass (t/ha) Conv	CM	Mean
Excalibur	0	0.619		0.619	2.426		2.426	0.381		0.381	3.427		3.427
Excalibur	240	1.541	1.683	1.612	3.969	4.158	4.063	0.636	0.654	0.645	6.145	6.495	6.320
Excalibur	Mean	1.080	1.151	1.116	3.197	3.292	3.244	0.509	0.518	0.513	4.786	4.961	4.873
PR45D03	0	0.825		0.825	2.248		2.248	0.555		0.555	3.628		3.628
PR45D03	240	2.043	2.061	2.052	3.212	2.936	3.074	0.719	0.710	0.714	5.975	5.707	5.841
PR45D03	Mean	1.434	1.443	1.439	2.730	2.592	2.661	0.637	0.632	0.635	4.801	4.667	4.734
Exc+D03	0	0.722		0.722	2.337		2.337	0.468		0.468	3.527		3.527
Exc+D03	240	1.792	1.872	1.832	3.591	3.547	3.569	0.678	0.682	0.680	6.060	6.101	6.080
Exc+D03	Mean	1.257	1.297	1.277	2.964	2.942	2.953	0.573	0.575	0.574	4.793	4.814	4.804
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		21	0.0739	<0.001	21	0.1895	0.006	21	0.0397	0.006	21	0.279	0.624
N management		21	0.0739	0.591	21	0.1895	0.909	21	0.0397	0.957	21	0.279	0.942
Nrate		21	0.0739	<0.001	21	0.1895	<0.001	21	0.0397	<0.001	21	0.279	<0.001
Var x Man		21	0.1045	0.679	21	0.2680	0.546	21	0.0561	0.860	21	0.395	0.586
Var x Nrate		21	0.1045	0.128	21	0.2680	0.044	21	0.0561	0.204	21	0.395	0.236
Man x Nrate		21	0.1045	0.591	21	0.2680	0.909	21	0.0561	0.957	21	0.395	0.942
Var x Man x Nrate		21	0.1478	0.679	21	0.3790	0.546	21	0.0793	0.860	21	0.558	0.586

Table 23. Terrington. Mid flowering measurement of nitrogen concentration in dry plant material on Treatments 1, 3 and 9 without Folicur.

Variety	N rate	Leaf N%			Other plant material N %			Total crop N (kg/ha)			Crop N (kg N/ha) per unit GAI		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	2.17		2.17	1.41		1.41	27.5		27.5	47.3		47.3
Excalibur	240	3.97	4.52	4.24	2.26	2.36	2.31	114.2	116.2	115.2	55.0	60.7	57.8
Excalibur	Mean	3.07	3.34	3.20	1.84	1.89	1.86	70.8	71.8	71.3	51.1	54.0	52.6
PR45D03	0	2.07		2.07	1.43		1.43	28.2		28.2	48.3		48.3
PR45D03	240	4.59	4.23	4.41	2.55	2.48	2.51	141.5	95.4	118.5	65.6	51.4	58.5
PR45D03	Mean	3.33	3.15	3.24	1.99	1.95	1.97	84.8	61.8	73.3	56.9	49.8	53.4
Exc+D03	0	2.12		2.12	1.42		1.42	27.8		27.8	47.8		47.8
Exc+D03	240	4.28	4.37	4.33	2.41	2.42	2.41	127.8	105.8	116.8	60.3	56.0	58.2
Exc+D03	Mean	3.20	3.24	3.22	1.91	1.92	1.92	77.8	66.8	72.3	54.0	51.9	53.0
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		21	0.1152	0.770	21	0.0844	0.212	21	9.31	0.833	21	2.59	0.755
N management		21	0.1152	0.690	21	0.0844	0.944	21	9.31	0.250	21	2.59	0.422
Nrate		21	0.1152	<0.001	21	0.0844	<0.001	21	9.31	<0.001	21	2.59	<0.001
Var x Man		21	0.1629	0.061	21	0.1193	0.620	21	13.17	0.211	21	3.66	0.067
Var x Nrate		21	0.1629	0.254	21	0.1193	0.294	21	13.17	0.890	21	3.66	0.942
Man x Nrate		21	0.1629	0.690	21	0.1193	0.944	21	13.17	0.250	21	3.66	0.422
Var x Man x Nrate		21	0.2304	0.061	21	0.1687	0.620	21	18.62	0.211	21	5.17	0.067

Table 24. High Mowthorpe. Mid flowering measurement of nitrogen concentration in dry plant material on Treatments 1, 3 and 9 without Folicur.

Variety	N rate	Leaf N%			Other plant material N %			Total crop N (kg/ha)			Crop N (kg N/ha) per unit GAI		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	2.55		2.55	1.35		1.35	37.5		37.5	71.8		71.8
Excalibur	240	3.21	4.09	3.65	2.78	2.57	2.67	190.6	160.3	175.5	65.8	59.8	62.8
Excalibur	Mean	2.88	3.32	3.10	2.06	1.96	2.01	114.0	98.9	106.5	68.8	65.8	67.3
PR45D03	0	2.78		2.78	1.40		1.40	32.2		32.2	64.3		64.3
PR45D03	240	4.98	4.31	4.65	2.85	3.20	3.03	171.9	195.9	183.9	46.6	52.0	49.3
PR45D03	Mean	3.88	3.54	3.71	2.12	2.30	2.21	102.1	114.1	108.1	55.5	58.2	56.8
Exc+D03	0	2.66		2.66	1.37		1.37	34.8		34.8	68.1		68.1
Exc+D03	240	4.10	4.20	4.15	2.81	2.89	2.85	181.3	178.1	179.7	56.2	55.9	56.1
Exc+D03	Mean	3.38	3.43	3.41	2.09	2.13	2.11	108.1	106.5	107.3	62.1	62.0	62.1
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		14	0.1271	<0.001	14	0.1959	0.319	14	9.25	0.865	14	4.21	0.026
N management		14	0.1271	0.692	14	0.1959	0.858	14	9.25	0.866	14	4.21	0.974
Nrate		14	0.1271	<0.001	14	0.1959	<0.001	14	9.25	<0.001	14	4.21	0.013
Var x Man		14	0.1797	0.009	14	0.2770	0.481	14	13.08	0.165	14	5.96	0.508
Var x Nrate		14	0.1797	0.009	14	0.2770	0.452	14	13.08	0.472	14	5.96	0.493
Man x Nrate		14	0.1797	0.692	14	0.2770	0.858	14	13.08	0.866	14	5.96	0.974
Var x Man x Nrate		14	0.2542	0.009	14	0.3918	0.481	14	18.49	0.165	14	8.42	0.508

Table 25. Rosemaund. Mid flowering measurement of nitrogen concentration in dry plant material on Treatments 1, 3 and 9 without Folicur.

Variety	N rate kg/ha	Leaf N% Conv	Leaf N% CM	Leaf N% Mean	Other plant material N % Conv	Other plant material N % CM	Other plant material N % Mean	Total crop N (kg/ha) Conv	Total crop N (kg/ha) CM	Total crop N (kg/ha) Mean	Crop N (kg N/ha) per unit GAI Conv	Crop N (kg N/ha) per unit GAI CM	Crop N (kg N/ha) per unit GAI Mean
Excalibur	0	3.02		3.02	1.42		1.42	61.2		61.2	44.9		44.9
Excalibur	240	4.98	5.34	5.16	2.97	3.09	3.03	220.0	240.0	230.0	51.6	51.7	51.6
Excalibur	Mean	4.00	4.18	4.09	2.20	2.26	2.23	140.6	150.6	145.6	48.2	48.3	48.3
PR45D03	0	2.96		2.96	1.77		1.77	75.6		75.6	43.8		43.8
PR45D03	240	5.54	5.43	5.49	3.64	3.46	3.55	255.8	239.3	247.6	46.8	43.8	45.3
PR45D03	Mean	4.25	4.20	4.22	2.70	2.61	2.66	165.7	157.5	161.6	45.3	43.8	44.5
Exc+D03	0	2.99		2.99	1.59		1.59	68.4		68.4	44.3		44.3
Exc+D03	240	5.26	5.39	5.32	3.30	3.27	3.29	237.9	239.7	238.8	49.2	47.7	48.5
Exc+D03	Mean	4.13	4.19	4.16	2.45	2.43	2.44	153.2	154.1	153.6	46.8	46.0	46.4
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		21	0.0924	0.172	21	0.1199	0.002	21	12.03	0.197	21	1.622	0.032
N management		21	0.0924	0.498	21	0.1199	0.902	21	12.03	0.941	21	1.622	0.659
Nrate		21	0.0924	<0.001	21	0.1199	<0.001	21	12.03	<0.001	21	1.622	0.019
Var x Man		21	0.1307	0.223	21	0.1696	0.532	21	17.01	0.456	21	2.294	0.638
Var x Nrate		21	0.1307	0.049	21	0.1696	0.483	21	17.01	0.898	21	2.294	0.124
Man x Nrate		21	0.1307	0.498	21	0.1696	0.902	21	17.01	0.941	21	2.294	0.659
Var x Man x Nrate		21	0.1848	0.223	21	0.2399	0.532	21	24.06	0.456	21	3.245	0.638

Light interception at mid-flowering

At Terrington, there were no factors that significantly affected the amount of light reflected by the flowers (Table 26). There was, however, significantly greater interception of light by the flower layer in high N treatments and by PR45D03 relative to Excalibur (Table 27). Light interception at ground level was significantly increased by higher N rate and reduced by Folicur treatment (Table 28). There were no significant effects of Canopy Management.

At High Mowthorpe, light reflection by the flowers was significantly increased for PR45D03 relative to Excalibur (Table 29). Folicur also increased light reflection which is unusual. These differences were not replicated in measurements of light interception by the canopy, in which N rate was the only significant factor (Table 30). As at Terrington, higher N rate increased light interception at ground level (Table 31). There were no significant effects of Canopy Management.

At Rosemaund, as at High Mowthorpe, light reflection by the flowers was greater in PR45D03 than in Excalibur (Table 32). Folicur was also a significant factor, but had the opposite effect compared to High Mowthorpe. At Rosemaund Folicur reduced light reflection and increased the amount of light penetrating through the flower layer. Rosemaund was the only site at which Canopy Management had significant effects on light interception. Canopy Management reduced light reflection at 240 kg N/ha relative to Conventional management, but had little effect at 120 kg N/ha. This was supported by the observation that Canopy Management also reduced light interception by the flower layer at high N, allowing more light through to the leaves (Table 33), but did not affect light penetration to ground level (Table 34). There were small but significant effects of variety and N rate on light interception at ground level, with interception higher in PR45D03 and at higher N.

Table 26. Terrington. Percentage of light reflected from flowers.

Variety	N rate	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	120	7.72	7.14	7.43	7.80	6.65	7.23	7.76	6.90	7.33
Excalibur	240	7.98	7.19	7.58	7.49	7.53	7.51	7.74	7.36	7.55
Excalibur	Mean	7.85	7.16	7.51	7.65	7.09	7.37	7.75	7.13	7.44
PR45D03	120	8.11	7.99	8.05	8.19	8.01	8.10	8.15	8.00	8.07
PR45D03	240	7.30	7.63	7.46	7.63	9.05	8.34	7.46	8.34	7.90
PR45D03	Mean	7.70	7.81	7.75	7.91	8.53	8.22	7.81	8.17	7.99
Exc+D03	120	7.91	7.56	7.74	8.00	7.33	7.66	7.96	7.45	7.70
Exc+D03	240	7.64	7.41	7.52	7.56	8.29	7.93	7.60	7.85	7.72
Exc+D03	Mean	7.78	7.49	7.63	7.78	7.81	7.79	7.78	7.65	7.71

Treatment	df	SED	F pr.
Folicur	45	0.303	0.593
Variety	45	0.303	0.077
N management	45	0.303	0.670
Nrate	45	0.303	0.939
Fol x Var	45	0.428	0.325
Fol x Man	45	0.428	0.599
Var x Man	45	0.428	0.110
Fol x Nrate	45	0.428	0.434
Var x Nrate	45	0.428	0.526
Man x Nrate	45	0.428	0.217
Fol x Var x Man	45	0.605	0.752
Fol x Var x Nrate	45	0.605	0.571
Fol x Man x Nrate	45	0.605	0.300
Var x Man x Nrate	45	0.605	0.658
Fol x Var x Man x Nrate	45	0.856	0.917

Table 27. Terrington. Percentage of light interception by crop at base of flower layer.

Variety	N rate kg/ha	No Folicur Conv	CM	Mean	Folicur (0.5 l/ha) Conv	CM	Mean	Conv Mean	CM Mean	Grand Mean
Excalibur	120	25.4	39.6	32.5	34.3	37.1	35.7	29.8	38.4	34.1
Excalibur	240	38.5	39.0	38.7	34.0	41.7	37.9	36.3	40.4	38.3
Excalibur	Mean	31.9	39.3	35.6	34.2	39.4	36.8	33.0	39.4	36.2
PR45D03	120	41.2	42.7	42.0	39.0	41.2	40.1	40.1	41.9	41.0
PR45D03	240	49.1	46.4	47.7	45.1	44.1	44.6	47.1	45.3	46.2
PR45D03	Mean	45.2	44.5	44.8	42.0	42.7	42.3	43.6	43.6	43.6
Exc+D03	120	33.3	41.1	37.2	36.6	39.2	37.9	35.0	40.2	37.6
Exc+D03	240	43.8	42.7	43.2	39.6	42.9	41.2	41.7	42.8	42.2
Exc+D03	Mean	38.5	41.9	40.2	38.1	41.0	39.6	38.3	41.5	39.9

Treatment	df	SED	F pr.
Folicur	45	1.840	0.721
Variety	45	1.840	<0.001
N management	45	1.840	0.093
Nrate	45	1.840	0.015
Fol x Var	45	2.603	0.323
Fol x Man	45	2.603	0.908
Var x Man	45	2.603	0.094
Fol x Nrate	45	2.603	0.471
Var x Nrate	45	2.603	0.802
Man x Nrate	45	2.603	0.278
Fol x Var x Man	45	3.681	0.641
Fol x Var x Nrate	45	3.681	0.703
Fol x Man x Nrate	45	3.681	0.193
Var x Man x Nrate	45	3.681	0.914
Fol x Var x Man x Nrate	45	5.206	0.239

Table 28. Terrington. Percentage of light intercepted by crop at ground level.

Variety	N rate	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	120	83.4	86.9	85.2	86.8	83.3	85.1	85.1	85.1	85.1
Excalibur	240	90.7	91.2	90.9	88.2	90.6	89.4	89.4	90.9	90.2
Excalibur	Mean	87.1	89.0	88.0	87.5	87.0	87.2	87.3	88.0	87.6
PR45D03	120	93.2	89.1	91.1	85.7	81.0	83.4	89.5	85.0	87.2
PR45D03	240	94.5	92.1	93.3	90.6	93.1	91.8	92.5	92.6	92.6
PR45D03	Mean	93.8	90.6	92.2	88.2	87.0	87.6	91.0	88.8	89.9
Exc+D03	120	88.3	88.0	88.2	86.3	82.2	84.2	87.3	85.1	86.2
Exc+D03	240	92.6	91.6	92.1	89.4	91.9	90.6	91.0	91.8	91.4
Exc+D03	Mean	90.4	89.8	90.1	87.8	87.0	87.4	89.1	88.4	88.8

Treatment	df	SED	F pr.
Folicur	45	1.209	0.030
Variety	45	1.209	0.067
N management	45	1.209	0.557
Nrate	45	1.209	<0.001
Fol x Var	45	1.710	0.123
Fol x Man	45	1.710	0.931
Var x Man	45	1.710	0.236
Fol x Nrate	45	1.710	0.317
Var x Nrate	45	1.710	0.910
Man x Nrate	45	1.710	0.227
Fol x Var x Man	45	2.418	0.346
Fol x Var x Nrate	45	2.418	0.119
Fol x Man x Nrate	45	2.418	0.144
Var x Man x Nrate	45	2.418	0.534
Fol x Var x Man x Nrate	45	3.420	0.729

Table 29. High Mowthorpe. Percentage of light reflected from flowers.

Variety	N rate	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	120	7.88	8.54	8.21	8.71	9.84	9.28	8.30	9.19	8.74
Excalibur	240	8.30	8.70	8.50	8.58	8.92	8.75	8.44	8.81	8.63
Excalibur	Mean	8.09	8.62	8.36	8.65	9.38	9.01	8.37	9.00	8.68
PR45D03	120	13.30	14.35	13.83	15.71	15.39	15.55	14.51	14.87	14.69
PR45D03	240	13.75	13.58	13.66	14.70	15.44	15.07	14.23	14.51	14.37
PR45D03	Mean	13.53	13.96	13.74	15.21	15.42	15.31	14.37	14.69	14.53
Exc+D03	120	10.59	11.44	11.02	12.21	12.62	12.41	11.40	12.03	11.72
Exc+D03	240	11.03	11.14	11.08	11.64	12.18	11.91	11.33	11.66	11.50
Exc+D03	Mean	10.81	11.29	11.05	11.93	12.40	12.16	11.37	11.84	11.61

Treatment	df	SED	F pr.
Folicur	30	0.422	0.013
Variety	30	0.422	<0.001
N management	30	0.422	0.267
Nrate	30	0.422	0.608
Fol x Var	30	0.597	0.289
Fol x Man	30	0.597	0.990
Var x Man	30	0.597	0.716
Fol x Nrate	30	0.597	0.506
Var x Nrate	30	0.597	0.812
Man x Nrate	30	0.597	0.722
Fol x Var x Man	30	0.845	0.801
Fol x Var x Nrate	30	0.845	0.766
Fol x Man x Nrate	30	0.845	0.608
Var x Man x Nrate	30	0.845	0.796
Fol x Var x Man x Nrate	30	1.194	0.414

Table 30. High Mowthorpe. Percentage of light intercepted by crop at base of flower layer.

Variety	N rate	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	120	39.3	50.2	44.8	50.4	43.6	47.0	44.8	46.9	45.9
Excalibur	240	47.8	47.9	47.8	49.2	50.5	49.9	48.5	49.2	48.9
Excalibur	Mean	43.5	49.0	46.3	49.8	47.1	48.4	46.7	48.1	47.4
PR45D03	120	46.9	45.8	46.4	41.6	38.7	40.2	44.2	42.3	43.3
PR45D03	240	52.3	54.7	53.5	49.9	50.7	50.3	51.1	52.7	51.9
PR45D03	Mean	49.6	50.3	49.9	45.7	44.7	45.2	47.7	47.5	47.6
Exc+D03	120	43.1	48.0	45.6	46.0	41.2	43.6	44.5	44.6	44.6
Exc+D03	240	50.0	51.3	50.7	49.6	50.6	50.1	49.8	51.0	50.4
Exc+D03	Mean	46.6	49.7	48.1	47.8	45.9	46.8	47.2	47.8	47.5

Treatment	df	SED	F pr.
Folicur	30	2.12	0.555
Variety	30	2.12	0.921
N management	30	2.12	0.772
Nrate	30	2.12	0.010
Fol x Var	30	3.00	0.118
Fol x Man	30	3.00	0.252
Var x Man	30	3.00	0.717
Fol x Nrate	30	3.00	0.743
Var x Nrate	30	3.00	0.192
Man x Nrate	30	3.00	0.791
Fol x Var x Man	30	4.25	0.447
Fol x Var x Nrate	30	4.25	0.709
Fol x Man x Nrate	30	4.25	0.272
Var x Man x Nrate	30	4.25	0.564
Fol x Var x Man x Nrate	30	6.01	0.282

Table 31. High Mowthorpe. Percentage of light intercepted by crop at ground level.

Variety	N rate	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	120	91.8	92.2	92.0	92.1	90.4	91.3	92.0	91.3	91.6
Excalibur	240	95.7	96.3	96.0	96.6	97.2	96.9	96.2	96.8	96.5
Excalibur	Mean	93.8	94.3	94.0	94.4	93.8	94.1	94.1	94.0	94.0
PR45D03	120	89.1	89.6	89.4	92.5	91.4	91.9	90.8	90.5	90.7
PR45D03	240	97.2	95.8	96.5	96.5	97.5	97.0	96.8	96.6	96.7
PR45D03	Mean	93.2	92.7	92.9	94.5	94.4	94.5	93.8	93.6	93.7
Exc+D03	120	90.5	90.9	90.7	92.3	90.9	91.6	91.4	90.9	91.2
Exc+D03	240	96.5	96.1	96.3	96.5	97.3	96.9	96.5	96.7	96.6
Exc+D03	Mean	93.5	93.5	93.5	94.4	94.1	94.3	93.9	93.8	93.9

Treatment	df	SED	F pr.
Folicur	30	0.723	0.282
Variety	30	0.723	0.630
N management	30	0.723	0.845
Nrate	30	0.723	<0.001
Fol x Var	30	1.023	0.323
Fol x Man	30	1.023	0.836
Var x Man	30	1.023	0.878
Fol x Nrate	30	1.023	0.876
Var x Nrate	30	1.023	0.390
Man x Nrate	30	1.023	0.638
Fol x Var x Man	30	1.447	0.615
Fol x Var x Nrate	30	1.447	0.201
Fol x Man x Nrate	30	1.447	0.305
Var x Man x Nrate	30	1.447	0.702
Fol x Var x Man x Nrate	30	2.046	0.734

Table 32. Rosemaund. Percentage of light reflected by flowers.

Variety	N rate	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	120	12.6	12.9	12.8	12.2	12.3	12.2	12.4	12.6	12.5
Excalibur	240	12.9	12.8	12.8	13.2	12.4	12.8	13.1	12.6	12.8
Excalibur	Mean	12.8	12.8	12.8	12.7	12.3	12.5	12.7	12.6	12.6
PR45D03	120	16.9	17.2	17.1	16.1	16.6	16.3	16.5	16.9	16.7
PR45D03	240	16.6	15.9	16.3	15.7	14.5	15.1	16.2	15.2	15.7
PR45D03	Mean	16.8	16.6	16.7	15.9	15.5	15.7	16.3	16.0	16.2
Exc+D03	120	14.8	15.0	14.9	14.1	14.4	14.3	14.5	14.7	14.6
Exc+D03	240	14.7	14.4	14.5	14.5	13.4	13.9	14.6	13.9	14.2
Exc+D03	Mean	14.8	14.7	14.7	14.3	13.9	14.1	14.5	14.3	14.4

Treatment	df	SED	F pr.
Folicur	45	0.213	0.005
Variety	45	0.213	<0.001
N management	45	0.213	0.289
Nrate	45	0.213	0.114
Fol x Var	45	0.301	0.121
Fol x Man	45	0.301	0.437
Var x Man	45	0.301	0.774
Fol x Nrate	45	0.301	0.893
Var x Nrate	45	0.301	0.003
Man x Nrate	45	0.301	0.025
Fol x Var x Man	45	0.426	0.784
Fol x Var x Nrate	45	0.426	0.297
Fol x Man x Nrate	45	0.426	0.372
Var x Man x Nrate	45	0.426	0.411
Fol x Var x Man x Nrate	45	0.602	0.914

Table 33. Rosemaund. Percentage of light intercepted by crop at base of flower layer.

Variety	N rate	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	120	70.1	70.3	70.2	65.7	68.6	67.2	67.9	69.5	68.7
Excalibur	240	73.5	68.9	71.2	76.1	68.2	72.2	74.8	68.6	71.7
Excalibur	Mean	71.8	69.6	70.7	70.9	68.4	69.7	71.3	69.0	70.2
PR45D03	120	71.0	74.3	72.7	67.4	71.5	69.5	69.2	72.9	71.1
PR45D03	240	73.6	72.9	73.2	69.0	64.7	66.9	71.3	68.8	70.0
PR45D03	Mean	72.3	73.6	73.0	68.2	68.1	68.2	70.3	70.9	70.6
Exc+D03	120	70.6	72.3	71.4	66.6	70.1	68.3	68.6	71.2	69.9
Exc+D03	240	73.5	70.9	72.2	72.6	66.5	69.5	73.0	68.7	70.9
Exc+D03	Mean	72.0	71.6	71.8	69.6	68.3	68.9	70.8	69.9	70.4

Treatment	df	SED	F pr.
Folicur	45	1.270	0.026
Variety	45	1.270	0.765
N management	45	1.270	0.496
Nrate	45	1.270	0.443
Fol x Var	45	1.795	0.147
Fol x Man	45	1.795	0.732
Var x Man	45	1.795	0.254
Fol x Nrate	45	1.795	0.873
Var x Nrate	45	1.795	0.120
Man x Nrate	45	1.795	0.009
Fol x Var x Man	45	2.539	0.817
Fol x Var x Nrate	45	2.539	0.165
Fol x Man x Nrate	45	2.539	0.304
Var x Man x Nrate	45	2.539	0.753
Fol x Var x Man x Nrate	45	3.591	0.871

Table 34. Rosemaund. Percentage of light intercepted by crop at ground level.

Variety	N rate	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	120	97.3	97.1	97.2	96.4	96.0	97.3	96.9	96.5	96.7
Excalibur	240	98.6	97.8	98.2	98.9	98.6	98.6	98.8	98.2	98.5
Excalibur	Mean	98.0	97.4	97.7	97.7	97.3	98.0	97.8	97.4	97.6
PR45D03	120	98.0	98.5	98.2	98.0	98.1	98.0	98.0	98.3	98.2
PR45D03	240	99.6	99.4	99.5	99.3	98.9	99.6	99.4	99.1	99.3
PR45D03	Mean	98.8	98.9	98.9	98.6	98.5	98.8	98.7	98.7	98.7
Exc+D03	120	97.6	97.8	97.7	97.2	97.1	97.1	97.4	97.4	97.4
Exc+D03	240	99.1	98.6	98.8	99.1	98.7	98.9	99.1	98.7	98.9
Exc+D03	Mean	98.4	98.2	98.3	98.2	97.9	98.0	98.3	98.0	98.2

Treatment	df	SED	F pr.
Folicur	45	0.211	0.235
Variety	45	0.211	<0.001
N management	45	0.211	0.312
Nrate	45	0.211	<0.001
Fol x Var	45	0.298	0.882
Fol x Man	45	0.298	0.850
Var x Man	45	0.298	0.230
Fol x Nrate	45	0.298	0.114
Var x Nrate	45	0.298	0.125
Man x Nrate	45	0.298	0.302
Fol x Var x Man	45	0.422	0.663
Fol x Var x Nrate	45	0.422	0.044
Fol x Man x Nrate	45	0.422	0.596
Var x Man x Nrate	45	0.422	0.676
Fol x Var x Man x Nrate	45	0.596	0.770

Crop height

At all sites, there was a large and significant difference in height between Excalibur and the semi-dwarf PR45D03. Higher N significantly increased crop height at High Mowthorpe (Table 36). Canopy Management significantly reduced height at Terrington and Rosemaund, relative to Conventional management (Tables 35 and 37).

At Terrington, Excalibur was 32 cm taller than PR45D03 and Canopy Management reduced crop height by 2 cm (Table 35). Height was not significantly affected by N rate or Folicur treatment

At High Mowthorpe, Excalibur was 10 cm taller than PR45D03 (Table 36). Excalibur also responded to higher N rate, with an increase of 7 cm from 120 kg N/ha to 240 kg N/ha in Excalibur but not at all in PR45D03.

At Rosemaund, Excalibur was 41 cm taller than PR45D03 and Canopy Management reduced crop height by 4 cm (Table 37). Folicur treatment reduced height by 7 cm at 120 kg N/ha, but did not affect height at 240 kg N/ha.

Table 35. Terrington. Height (cm) to the top of terminal raceme.

Variety	N rate	No Folicur			Folicur (1.0 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	120	113.6	114.3	113.9	114.0	112.8	113.4	113.8	113.5	113.7
Excalibur	240	111.9	110.9	111.4	116.0	110.9	113.5	114.0	110.9	112.4
Excalibur	Mean	112.8	112.6	112.7	115.0	111.8	113.4	113.9	112.2	113.1
PR45D03	120	84.6	80.0	82.3	84.7	81.0	82.8	84.6	80.5	82.6
PR45D03	240	80.1	79.6	79.9	81.0	81.0	81.0	80.6	80.3	80.5
PR45D03	Mean	82.3	79.8	81.1	82.9	81.0	81.9	82.6	80.4	81.5
Exc+D03	120	99.1	97.1	98.1	99.4	96.9	98.1	99.2	97.0	98.1
Exc+D03	240	96.0	95.3	95.6	98.5	95.9	97.2	97.3	95.6	96.4
Exc+D03	Mean	97.6	96.2	96.9	98.9	96.4	97.7	98.3	96.3	97.3

Treatment	df	SED	F pr.
Folicur	45	0.930	0.393
Variety	45	0.930	<0.001
N management	45	0.930	0.043
Nrate	45	0.930	0.078
Fol x Var	45	1.316	0.956
Fol x Man	45	1.316	0.530
Var x Man	45	1.316	0.789
Fol x Nrate	45	1.316	0.396
Var x Nrate	45	1.316	0.640
Man x Nrate	45	1.316	0.777
Fol x Var x Man	45	1.860	0.327
Fol x Var x Nrate	45	1.860	0.597
Fol x Man x Nrate	45	1.860	0.722
Var x Man x Nrate	45	1.860	0.077
Fol x Var x Man x Nrate	45	2.631	0.815

Table 36. High Mowthorpe. Height (cm) to the top of terminal raceme.

Variety	N rate	No Folicur			Folicur (1.0 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	120	109.3	108.3	108.8	111.3	109.2	110.3	110.3	108.7	109.5
Excalibur	240	118.3	114.4	116.4	115.2	116.8	116.0	116.8	115.6	116.2
Excalibur	Mean	113.8	111.3	112.6	113.3	113.0	113.1	113.5	112.1	112.8
PR45D03	120	102.5	104.1	103.3	101.0	101.4	101.2	101.8	102.8	102.3
PR45D03	240	104.5	102.4	103.5	101.3	103.0	102.2	102.9	102.7	102.8
PR45D03	Mean	103.5	103.3	103.4	101.2	102.2	101.7	102.3	102.7	102.5
Exc+D03	120	105.9	106.2	106.0	106.2	105.3	105.7	106.0	105.7	105.9
Exc+D03	240	111.4	108.4	109.9	108.3	109.9	109.1	109.8	109.1	109.5
Exc+D03	Mean	108.6	107.3	108.0	107.2	107.6	107.4	107.9	107.4	107.7

Treatment	df	SED	F pr.
Folicur	32	1.055	0.591
Variety	32	1.055	<0.001
N management	32	1.055	0.646
Nrate	32	1.055	0.002
Fol x Var	32	1.492	0.299
Fol x Man	32	1.492	0.418
Var x Man	32	1.492	0.407
Fol x Nrate	32	1.492	0.791
Var x Nrate	32	1.492	0.007
Man x Nrate	32	1.492	0.852
Fol x Var x Man	32	2.110	0.837
Fol x Var x Nrate	32	2.110	0.526
Fol x Man x Nrate	32	2.110	0.179
Var x Man x Nrate	32	2.110	0.703
Fol x Var x Man x Nrate	32	2.983	0.837

Table 37. Rosemaund. Height (cm) to the top of terminal raceme.

Variety	N rate	No Folicur			Folicur (1.0 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	120	146.2	141.5	143.8	140.4	138.5	139.4	143.3	140.0	141.6
Excalibur	240	144.5	138.7	141.6	146.5	139.8	143.1	145.5	139.2	142.4
Excalibur	Mean	145.4	140.1	142.7	143.4	139.1	141.3	144.4	139.6	142.0
PR45D03	120	105.3	107.7	106.5	97.7	97.2	97.4	101.5	102.4	102.0
PR45D03	240	102.8	97.2	100.0	102.9	95.0	98.9	102.8	96.1	99.5
PR45D03	Mean	104.0	102.5	103.2	100.3	96.1	98.2	102.1	99.3	100.7
Exc+D03	120	125.7	124.6	125.1	119.0	117.8	118.4	122.4	121.2	121.8
Exc+D03	240	123.6	118.0	120.8	124.7	117.4	121.0	124.2	117.7	120.9
Exc+D03	Mean	124.7	121.3	123.0	121.9	117.6	119.7	123.3	119.4	121.4

Treatment	df	SED	F pr.
Folicur	45	1.725	0.067
Variety	45	1.725	<0.001
N management	45	1.725	0.031
Nrate	45	1.725	0.617
Fol x Var	45	2.440	0.303
Fol x Man	45	2.440	0.803
Var x Man	45	2.440	0.579
Fol x Nrate	45	2.440	0.050
Var x Nrate	45	2.440	0.350
Man x Nrate	45	2.440	0.130
Fol x Var x Man	45	3.451	0.604
Fol x Var x Nrate	45	3.451	0.762
Fol x Man x Nrate	45	3.451	0.827
Var x Man x Nrate	45	3.451	0.501
Fol x Var x Man x Nrate	45	4.880	0.753

Lodging

At Terrington, there were high levels of leaning at 10-45^o, caused by bending of the stems (Table 38), but no severe lodging (stems displaced at at an angle of >45^o). Lodging was significantly affected by increasing N rate, up to a rate of 120 kg N/ha, at which 100% of plot area was lodged in both varieties and both Folicur treatments.

There was no lodging at High Mowthorpe and Rosemaund.

Table 38. Terrington. Percent of plot lodged at 10-45 degrees at harvest.

Variety	N rate kg/ha	No Folicur Conv	No Folicur CM	No Folicur Mean	Folicur (0.5 l/ha) Conv	Folicur (0.5 l/ha) CM	Folicur (0.5 l/ha) Mean	Conv Mean	CM Mean	Grand Mean
Excalibur	0	25.0		25.0	0.0		0.0	12.5		12.5
Excalibur	60	100.0	100.0	100.0	75.0	75.0	75.0	87.5	87.5	87.5
Excalibur	120	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Excalibur	180	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Excalibur	240	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Excalibur	300	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Excalibur	360	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Excalibur	Mean	89.3	89.3	89.3	82.1	82.1	82.1	85.7	85.7	85.7
PR45D03	0	0.0		0.0	75.0		75.0	37.5		37.5
PR45D03	60	100.0	75.0	87.5	100.0	75.0	87.5	100.0	75.0	87.5
PR45D03	120	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
PR45D03	180	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
PR45D03	240	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
PR45D03	300	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
PR45D03	360	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
PR45D03	Mean	85.7	82.1	83.9	96.4	92.9	94.6	91.1	87.5	89.3
Exc+D03	0	12.5		12.5	37.5		37.5	25.0		25.0
Exc+D03	60	100.0	87.5	93.8	87.5	75.0	81.3	93.8	81.3	87.5
Exc+D03	120	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Exc+D03	180	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Exc+D03	240	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Exc+D03	300	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Exc+D03	360	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Exc+D03	Mean	87.5	85.7	86.6	89.3	87.5	88.4	88.4	86.6	87.5

Treatment	df	SED	F pr.
Folicur	165	2.49	0.475
Variety	165	2.49	0.154
N management	165	2.49	0.475
N rate	165	4.67	<0.001
Fol x Var	165	3.53	<0.001
Fol x Man	165	3.53	1.000
Var x Man	165	3.53	0.475
Fol x Nrate	165	6.60	0.010
Var x Nrate	165	6.60	0.062
Man x Nrate	165	6.60	0.798
Fol x Var x Man	165	4.99	1.000
Fol x Var x Nrate	165	9.33	<0.001
Fol x Man x Nrate	165	9.33	1.000
Var x Man x Nrate	165	9.33	0.798
Fol x Var x Man x Nrate	165	13.20	1.000

Biomass at harvest

At Terrington, increasing N rate from 0 to 240 kg N/ha significantly increased the biomass of seed and pod walls, and the total biomass. There were no significant effects of variety or Canopy Management (Table 39).

At High Mowthorpe, increasing N rate from 0 to 240 kg N/ha significantly increased the biomass of seed, stems and pod walls, and the total biomass. Excalibur had a significantly higher seed biomass than PR45D03. There were no significant effects of variety on the other biomass components or of Canopy Management (Table 40).

At Rosemaund, increased N rate significantly increased the biomass of seed, stems and pod walls, and the total biomass. PR45D03 had significantly higher seed biomass than Excalibur. Stem biomass was higher for Excalibur than PR45D03, and Excalibur showed a greater increase in stem biomass with increased N rate, although these results were not significant (P=0.066, P=0.083 respectively). There were no significant effects of Canopy Management (Table 41).

It is interesting to observe that there were no significant differences between the varieties for total biomass and stem biomass. Across the sites, the average total biomass was 9.73 t/ha for Excalibur and 9.86 t/ha for PR45D03. The average stem biomass was 3.45 t/ha for Excalibur and 3.38 t/ha for PR45D03. The similarity in stem biomass between varieties was unexpected given the height differences and may have resulted from PR55D03 having more branches.

Table 39. Terrington. Pre-harvest measurement of dry matter (t/ha) for plots without Folicur.

Variety	N rate	Total plant dry matter (t/ha)			Seed dry matter (t/ha)			Stem dry matter (t/ha)			Pod wall dry matter (t/ha)		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	3.61		3.61	1.16		1.16	1.44		1.44	1.01		1.01
Excalibur	240	9.45	8.97	9.21	3.76	3.74	3.75	3.20	2.61	2.91	2.49	2.62	2.55
Excalibur	Mean	6.53	6.29	6.41	2.46	2.45	2.46	2.32	2.02	2.17	1.75	1.81	1.78
PR45D03	0	4.80		4.80	1.21		1.21	2.79		2.79	0.79		0.79
PR45D03	240	9.63	10.50	10.06	3.96	3.98	3.97	2.86	2.92	2.89	2.81	3.60	3.20
PR45D03	Mean	7.21	7.65	7.43	2.59	2.60	2.59	2.83	2.86	2.84	1.80	2.19	2.00
Exc+D03	0	4.20		4.20	1.19		1.19	2.11		2.11	0.90		0.90
Exc+D03	240	9.54	9.73	9.64	3.86	3.86	3.86	3.03	2.77	2.90	2.65	3.11	2.88
Exc+D03	Mean	6.87	6.97	6.92	2.52	2.52	2.52	2.57	2.44	2.51	1.78	2.00	1.89
Treatment		df	SED	F Pr.	df	SED	F Pr.	df	SED	F Pr.	df	SED	F Pr.
Variety		21	0.831	0.234	21	0.0817	0.120	21	0.650	0.314	21	0.315	0.502
N management		21	0.831	0.908	21	0.0817	0.997	21	0.650	0.840	21	0.315	0.475
Nrate		21	0.831	<0.001	21	0.0817	<0.001	21	0.650	0.240	21	0.315	<0.001
Var x Man		21	1.175	0.688	21	0.1155	0.900	21	0.920	0.804	21	0.446	0.607
Var x Nrate		21	1.175	0.842	21	0.1155	0.333	21	0.920	0.305	21	0.446	0.182
Man x Nrate		21	1.175	0.908	21	0.1155	0.997	21	0.920	0.840	21	0.446	0.475
Var x Man x Nrate		21	1.662	0.688	21	0.1633	0.900	21	1.301	0.804	21	0.630	0.607

Table 40. High Mowthorpe. Pre-harvest measurement of dry matter (t/ha) for plots without Folicur.

Variety	N rate	Total plant dry matter (t/ha)			Seed dry matter (t/ha)			Stem dry matter (t/ha)			Pod wall dry matter (t/ha)		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	8.43		8.43	1.92		1.92	2.82		2.82	3.69		3.69
Excalibur	240	18.55	15.10	16.82	4.16	3.86	4.01	6.80	5.58	6.19	7.59	5.66	6.62
Excalibur	Mean	13.49	11.76	12.63	3.04	2.89	2.97	4.81	4.20	4.50	5.64	4.68	5.16
PR45D03	0	8.98		8.98	1.69		1.69	3.04		3.04	4.25		4.25
PR45D03	240	15.47	16.43	15.95	3.74	3.73	3.73	4.99	5.84	5.42	6.74	6.86	6.80
PR45D03	Mean	12.22	12.70	12.46	2.71	2.71	2.71	4.02	4.44	4.23	5.49	5.55	5.52
Exc+D03	0	8.70		8.70	1.80		1.80	2.93		2.93	3.97		3.97
Exc+D03	240	17.01	15.76	16.39	3.95	3.79	3.87	5.90	5.71	5.80	7.16	6.26	6.71
Exc+D03	Mean	12.86	12.23	12.54	2.88	2.80	2.84	4.41	4.32	4.37	5.57	5.11	5.34
Treatment		df	SED	F Pr.	df	SED	F Pr.	df	SED	F Pr.	df	SED	F Pr.
Variety		14	0.733	0.826	14	0.0859	0.010	14	0.280	0.345	14	0.451	0.432
N management		14	0.733	0.410	14	0.0859	0.380	14	0.280	0.745	14	0.451	0.333
Nrate		14	0.733	<0.001	14	0.0859	<0.001	14	0.280	<0.001	14	0.451	<0.001
Var x Man		14	1.037	0.155	14	0.1214	0.418	14	0.395	0.086	14	0.638	0.273
Var x Nrate		14	1.037	0.349	14	0.1214	0.788	14	0.395	0.096	14	0.638	0.684
Man x Nrate		14	1.037	0.410	14	0.1214	0.380	14	0.395	0.745	14	0.638	0.333
Var x Man x Nrate		14	1.466	0.155	14	0.1717	0.418	14	0.559	0.086	14	0.902	0.273

Table 41. Rosemaund. Pre-harvest measurement of dry matter (t/ha) for plots without Folicur.

Variety	N rate	Total plant dry matter (t/ha)			Seed dry matter (t/ha)			Stem dry matter (t/ha)			Pod wall dry matter (t/ha)		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	7.55		7.55	2.51		2.51	2.86		2.86	2.18		2.18
Excalibur	240	13.07	12.37	12.72	4.70	4.72	4.71	4.68	4.35	4.51	3.69	3.30	3.50
Excalibur	Mean	10.31	9.96	10.14	3.60	3.62	3.61	3.77	3.60	3.69	2.94	2.74	2.84
PR45D03	0	7.60		7.60	2.76		2.76	2.82		2.82	2.02		2.02
PR45D03	240	11.67	11.87	11.77	5.08	4.98	5.03	3.09	3.49	3.29	3.50	3.40	3.45
PR45D03	Mean	9.63	9.73	9.68	3.92	3.87	3.89	2.96	3.16	3.06	2.76	2.71	2.73
Exc+D03	0	7.58		7.58	2.64		2.64	2.84		2.84	2.10		2.10
Exc+D03	240	12.37	12.12	12.24	4.89	4.85	4.87	3.89	3.92	3.90	3.60	3.35	3.47
Exc+D03	Mean	9.97	9.85	9.91	3.76	3.74	3.75	3.36	3.38	3.37	2.85	2.72	2.79
Treatment		df	SED	F Pr.	df	SED	F Pr.	df	SED	F Pr.	df	SED	F Pr.
Variety		21	0.413	0.285	21	0.0931	0.006	21	0.324	0.066	21	0.1077	0.333
N management		21	0.413	0.767	21	0.0931	0.851	21	0.324	0.959	21	0.1077	0.265
Nrate		21	0.413	<0.001	21	0.0931	<0.001	21	0.324	0.004	21	0.1077	<0.001
Var x Man		21	0.583	0.591	21	0.1317	0.752	21	0.458	0.579	21	0.1523	0.508
Var x Nrate		21	0.583	0.245	21	0.1317	0.683	21	0.458	0.083	21	0.1523	0.596
Man x Nrate		21	0.583	0.767	21	0.1317	0.851	21	0.458	0.959	21	0.1523	0.265
Var x Man x Nrate		21	0.825	0.591	21	0.1862	0.752	21	0.648	0.579	21	0.2153	0.508

Crop N content

At Terrington, increasing N rate from 0 to 240 kg N/ha increased the total N uptake from 44 to 153 kg N/ha (Table 43). Increasing N rate also significantly increased the amount of N in the seed, and combined stems and pod walls. These effects were caused by a combination of greater biomass (Table 39) and greater tissue N concentration (Table 42). There were no significant differences between Excalibur and PR45D03 in total N uptake or the amount of N taken off in the seed, but Excalibur did show a greater response to increased N rate in seed N concentration. There were no significant effects of Canopy Management.

At High Mowthorpe, increasing N rate from 0 to 240 kg N/ha increased the total N uptake from 101 to 238 kg N/ha (Table 45). Increasing N rate also significantly increased the amount of N in the seed, and combined stems and pod walls. These effects were caused by a combination of greater biomass (Table 40) and greater tissue N concentration (Table 44). Excalibur had a significantly higher seed N yield, due to higher biomass rather than higher tissue N concentration. PR45D03 had significantly higher tissue N concentration in the stems and pod walls than Excalibur. There was no difference in total N uptake between the varieties, but the N offtake in the seed of Excalibur was about 8 kg N/ha greater than PR45D03. There were no significant effects of Canopy Management.

At Rosemaund, increasing N rate from 0 to 240 kg N/ha increased the total N uptake from 91 to 226 kg N/ha (Table 47). Increasing N rate also significantly increased the amount of N in the seed, and combined stems and pod walls. These effects were caused by a combination of greater biomass (Table 41) and greater tissue N concentration (Table 46). Variety had significant effects on N concentration, with Excalibur having higher seed N concentration, and PR45D03 higher N concentration in other parts of the plant. PR45D03 also showed a significantly greater N response in N concentration of stems and pod walls. There were no significant differences between Excalibur and PR45D03 in total N uptake or the amount of N taken off in the seed. There were no significant effects of Canopy Management.

Table 42. Terrington. Pre-harvest measurement of nitrogen concentration for plots without Folicur.

Variety	N rate	Seed N %			Stem and pod wall N %		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	2.235		2.235	0.532		0.532
Excalibur	240	2.872	2.969	2.920	0.702	0.755	0.728
Excalibur	Mean	2.553	2.602	2.577	0.617	0.643	0.630
PR45D03	0	2.465		2.465	0.505		0.505
PR45D03	240	2.651	2.766	2.709	0.797	0.833	0.815
PR45D03	Mean	2.553	2.610	2.582	0.651	0.669	0.660
Exc+D03	0	2.345		2.345	0.519		0.519
Exc+D03	240	2.762	2.867	2.814	0.749	0.794	0.772
Exc+D03	Mean	2.553	2.606	2.579	0.634	0.656	0.645
Treatment		df	SED	F pr.	df	SED	F pr.
Variety		21	0.0975	0.967	21	0.0399	0.462
N management		21	0.0975	0.593	21	0.0399	0.585
Nrate		21	0.0975	<0.001	21	0.0399	<0.001
Var x Man		21	0.1378	0.965	21	0.0564	0.916
Var x Nrate		21	0.1378	0.038	21	0.0564	0.169
Man x Nrate		21	0.1378	0.593	21	0.0564	0.585
Var x Man x Nrate		21	0.1949	0.965	21	0.0798	0.916

Table 43. Terrington. Pre-harvest measurement of N content for plots without Folicur.

Variety	N rate	Seed N yield (kg/ha)			Stem and pod wall N yield (kg/ha)			Total N yield (kg/ha)		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	26.0		26.0	13.0		13.0	39.1		39.1
Excalibur	240	108.6	111.1	109.8	40.7	40.4	40.6	149.3	151.5	150.4
Excalibur	Mean	67.3	68.5	67.9	26.9	26.7	26.8	94.2	95.3	94.7
PR45D03	0	30.0		30.0	19.0		19.0	49.1		49.1
PR45D03	240	104.4	110.6	107.5	45.6	52.2	48.9	150.0	162.8	156.4
PR45D03	Mean	67.2	70.3	68.8	32.3	35.6	34.0	99.6	105.9	102.7
Exc+D03	0	28.0		28.0	16.0		16.0	44.1		44.1
Exc+D03	240	106.5	110.8	108.7	43.2	46.3	44.7	149.7	157.1	153.4
Exc+D03	Mean	67.3	69.4	68.3	29.6	31.2	30.4	96.9	100.6	98.7
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		21	4.26	0.841	21	5.55	0.212	21	7.99	0.327
N management		21	4.26	0.617	21	5.55	0.779	21	7.99	0.644
Nrate		21	4.26	<0.001	21	5.55	<0.001	21	7.99	<0.001
Var x Man		21	6.03	0.832	21	7.84	0.760	21	11.29	0.745
Var x Nrate		21	6.03	0.468	21	7.84	0.837	21	11.29	0.806
Man x Nrate		21	6.03	0.617	21	7.84	0.779	21	11.29	0.644
Var x Man x Nrate		21	8.52	0.832	21	11.09	0.760	21	15.97	0.745

Table 44. High Mowthorpe. Pre-harvest measurement of nitrogen concentration for plots without Folicur.

Variety	N rate	Seed N %			Stem and pod wall N %		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	2.61		2.61	0.58		0.58
Excalibur	240	2.87	2.99	2.93	0.93	0.90	0.92
Excalibur	Mean	2.74	2.80	2.77	0.76	0.74	0.75
PR45D03	0	2.58		2.58	0.99		0.99
PR45D03	240	2.85	2.92	2.88	1.04	1.06	1.05
PR45D03	Mean	2.71	2.75	2.73	1.02	1.03	1.02
Exc+D03	0	2.59		2.59	0.79		0.79
Exc+D03	240	2.86	2.95	2.91	0.99	0.98	0.98
Exc+D03	Mean	2.73	2.77	2.75	0.89	0.88	0.89
Treatment		df	SED	F pr.	df	SED	F pr.
Variety		14	0.0613	0.506	14	0.0996	0.015
N management		14	0.0613	0.473	14	0.0996	0.986
Nrate		14	0.0613	<0.001	14	0.0996	0.068
Var x Man		14	0.0867	0.835	14	0.1409	0.890
Var x Nrate		14	0.0867	0.938	14	0.1409	0.184
Man x Nrate		14	0.0867	0.473	14	0.1409	0.986
Var x Man x Nrate		14	0.1226	0.835	14	0.1992	0.890

Table 45. High Mowthorpe. Pre-harvest measurement of N content for plots without Folicur.

Variety	N rate	Seed N yield (kg/ha)			Stem and pod wall N yield (kg/ha)			Total N yield (kg/ha)		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	50.1		50.1	38.3		38.3	88.4		88.4
Excalibur	240	119.6	115.4	117.5	137.0	102.0	119.5	256.6	217.4	237.0
Excalibur	Mean	84.8	82.8	83.8	87.7	70.1	78.9	172.5	152.9	162.7
PR45D03	0	43.3		43.3	71.1		71.1	114.4		114.4
PR45D03	240	107.2	108.3	107.8	124.1	137.3	130.7	231.3	245.6	238.5
PR45D03	Mean	75.3	75.8	75.5	97.6	104.2	100.9	172.9	180.0	176.5
Exc+D03	0	46.7		46.7	54.7		54.7	101.4		101.4
Exc+D03	240	113.4	111.9	112.6	130.5	119.7	125.1	243.9	231.5	237.7
Exc+D03	Mean	80.1	79.3	79.7	92.6	87.2	89.9	172.7	166.5	169.6
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		14	2.81	0.011	14	14.03	0.139	14	15.27	0.383
N management		14	2.81	0.790	14	14.03	0.704	14	15.27	0.691
Nrate		14	2.81	<0.001	14	14.03	<0.001	14	15.27	<0.001
Var x Man		14	3.98	0.650	14	19.84	0.404	14	21.59	0.396
Var x Nrate		14	3.98	0.603	14	19.84	0.456	14	21.59	0.435
Man x Nrate		14	3.98	0.790	14	19.84	0.704	14	21.59	0.691
Var x Man x Nrate		14	5.62	0.650	14	28.06	0.404	14	30.53	0.396

Table 46. Rosemaund. Pre-harvest measurement of nitrogen concentration for plots without Folicur.

Variety	N rate	Seed N %			Stem and pod wall N %		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	2.507		2.507	0.504		0.504
Excalibur	240	3.264	3.287	3.276	0.746	0.811	0.779
Excalibur	Mean	2.886	2.897	2.891	0.625	0.658	0.641
PR45D03	0	2.348		2.348	0.593		0.593
PR45D03	240	3.225	3.183	3.204	1.140	1.051	1.096
PR45D03	Mean	2.786	2.766	2.776	0.867	0.822	0.845
Exc+D03	0	2.428		2.428	0.549		0.549
Exc+D03	240	3.244	3.235	3.240	0.943	0.931	0.937
Exc+D03	Mean	2.836	2.831	2.834	0.746	0.740	0.743
Treatment		df	SED	F pr.	df	SED	F pr.
Variety		21	0.0423	0.012	21	0.0511	<0.001
N management		21	0.0423	0.916	21	0.0511	0.909
Nrate		21	0.0423	<0.001	21	0.0511	<0.001
Var x Man		21	0.0598	0.705	21	0.0723	0.459
Var x Nrate		21	0.0598	0.312	21	0.0723	0.037
Man x Nrate		21	0.0598	0.916	21	0.0723	0.909
Var x Man x Nrate		21	0.0845	0.705	21	0.1022	0.459

Table 47. Rosemaund. Pre-harvest measurement of N content for plots without Folicur.

Variety	N rate	Seed N yield (kg/ha)			Stem and pod wall N yield (kg/ha)			Total N yield (kg/ha))		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	62.8		62.8	25.3		25.3	88.1		88.1
Excalibur	240	153.7	155.3	154.5	63.1	62.6	62.9	216.8	218.0	217.4
Excalibur	Mean	108.2	109.1	108.6	44.2	44.0	44.1	152.4	153.0	152.7
PR45D03	0	64.7		64.7	28.3		28.3	93.0		93.0
PR45D03	240	163.5	158.6	161.1	76.2	72.5	74.4	239.7	231.1	235.4
PR45D03	Mean	114.1	111.7	112.9	52.3	50.4	51.3	166.4	162.1	164.2
Exc+D03	0	63.7		63.7	26.8		26.8	90.5		90.5
Exc+D03	240	158.6	157.0	157.8	69.6	67.6	68.6	228.3	224.5	226.4
Exc+D03	Mean	111.2	110.4	110.8	48.2	47.2	47.7	159.4	157.5	158.5
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		21	3.64	0.258	21	5.58	0.207	21	8.52	0.192
N management		21	3.64	0.823	21	5.58	0.855	21	8.52	0.830
Nrate		21	3.64	<0.001	21	5.58	<0.001	21	8.52	<0.001
Var x Man		21	5.15	0.657	21	7.88	0.886	21	12.05	0.777
Var x Nrate		21	5.15	0.527	21	7.88	0.457	21	12.05	0.449
Man x Nrate		21	5.15	0.823	21	7.88	0.855	21	12.05	0.830
Var x Man x Nrate		21	7.28	0.657	21	11.15	0.886	21	17.04	0.777

Seed size and seed number

At Terrington, Excalibur had a significantly higher thousand seed weight than PR45D03 by 0.4 g (Table 48). N rate also had a significant effect on seed weight. There were no significant effects of Folicur or Canopy Management. Seed number was significantly affected by Folicur, variety and nitrogen rate (Table 49), showing that that the yield benefit of Folicur treatment must have been caused by increasing seed weight, as seed number was reduced. The yield increase resulting from increased N was most closely related to increases in seed number. The greater seed weight of Excalibur relative to PR45D03 was balanced by higher seed numbers in PR45D03, resulting no significant difference in yield between the varieties.

At High Mowthorpe, Excalibur had a significantly higher thousand seed weight than PR45D03 by 0.14 g (Table 50). Inreased N rate reduced seed weight. There were no significant effects of Folicur or Canopy Management. Seed number was significantly increased by variety and greater nitrogen rate (Table 51), showing that the greater yield of Excalibur relative to PR45D03 was caused by both increased seed number and seed size. The yield increase resulting from increased N was most closely related to increases in seed number.

At Rosemaund, as at Terrington, Excalibur had a significantly higher thousand weight than PR45D03 by 0.4 g (Table 52). Increasing N rate also increased seed weight. There were no significant effects of Folicur or Canopy Management. Seed number was significantly affected by Folicur, variety and nitrogen rate (Table 53), showing that that the yield reduction with Folicur treatment was caused mainly by reducing seed number. The greater yield of PR45D03 relative to Excalibur was caused by greater seed number outweighing the effect of lower seed weight. The yield increase resulting from increased N was most closely related to increases in seed number.

Table 48. Terrington. Thousand seed weight.

Variety	N rate kg/ha	No Folicur Conv	No Folicur CM	No Folicur Mean	Folicur (0.5 l/ha) Conv	Folicur (0.5 l/ha) CM	Folicur (0.5 l/ha) Mean	Conv Mean	CM Mean	Grand Mean
Excalibur	0	5.36		5.36	5.50		5.50	5.43		5.43
Excalibur	120	5.04	5.12	5.08	5.11	5.25	5.18	5.08	5.18	5.13
Excalibur	240	5.40	5.32	5.36	5.38	5.52	5.45	5.39	5.42	5.40
Excalibur	360	5.48	5.53	5.50	5.56	5.44	5.50	5.52	5.48	5.50
Excalibur	Mean	5.32	5.33	5.32	5.39	5.43	5.41	5.35	5.38	5.37
PR45D03	0	5.11		5.11	5.14		5.14	5.13		5.13
PR45D03	120	4.77	4.84	4.81	4.81	4.84	4.82	4.79	4.84	4.82
PR45D03	240	4.91	4.94	4.93	4.97	4.91	4.94	4.94	4.93	4.93
PR45D03	360	4.96	4.92	4.94	4.88	5.05	4.96	4.92	4.99	4.95
PR45D03	Mean	4.94	4.95	4.95	4.95	4.99	4.97	4.95	4.97	4.96
Exc+D03	0	5.24		5.24	5.32		5.32	5.28		5.25
Exc+D03	120	4.91	4.98	4.94	4.96	5.05	5.00	4.93	5.01	4.97
Exc+D03	240	5.16	5.13	5.14	5.18	5.22	5.20	5.17	5.17	5.17
Exc+D03	360	5.22	5.22	5.22	5.22	5.24	5.23	5.22	5.23	5.23
Exc+D03	Mean	5.13	5.14	5.14	5.17	5.21	5.19	5.15	5.17	5.16

Treatment	df	SED	F pr.
Folicur	93	0.0337	0.124
Variety	93	0.0337	<0.001
N management	93	0.0337	0.459
Nrate	93	0.0477	<0.001
Fol x Var	93	0.0477	0.348
Fol x Man	93	0.0477	0.693
Var x Man	93	0.0477	0.981
Fol x Nrate	93	0.0674	0.869
Var x Nrate	93	0.0674	0.027
Man x Nrate	93	0.0674	0.832
Fol x Var x Man	93	0.0674	0.945
Fol x Var x Nrate	93	0.0953	0.902
Fol x Man x Nrate	93	0.0953	0.985
Var x Man x Nrate	93	0.0953	0.832
Fol x Var x Man x Nrate	93	0.1348	0.335

Table 49. Terrington. Seeds per m^2.

Variety	N rate kg/ha	No Folicur Conv	CM	Mean	Folicur (0.5 l/ha) Conv	CM	Mean	Conv Mean	CM Mean	Grand Mean
Excalibur	0	23971		23971	18762		18762	21367		21367
Excalibur	120	67924	62841	65382	62643	58984	60813	65283	60912	63098
Excalibur	240	76516	77362	76939	75935	72554	74244	76225	74958	75592
Excalibur	360	82623	75242	78933	79791	73786	76788	81207	74514	77860
Excalibur	Mean	62759	59854	61306	59283	56021	57652	61021	57938	59479
PR45D03	0	26091		26091	24749		24749	25420		25420
PR45D03	120	69937	69065	69501	71835	70091	70963	70886	69578	70232
PR45D03	240	88806	88661	88733	82540	83430	82985	85673	86046	85859
PR45D03	360	91462	84226	87844	85892	82211	84052	88677	83219	85948
PR45D03	Mean	69074	67011	68042	66254	65120	65687	67664	66066	66865
Exc+D03	0	25031		25031	21756		21756	23393		23393
Exc+D03	120	68930	65953	67442	67239	64537	65888	68085	65245	66665
Exc+D03	240	82661	83012	82836	79238	77992	78615	80949	80502	80726
Exc+D03	360	87043	79734	83388	82841	77999	80420	84942	78866	81904
Exc+D03	Mean	65916	63432	64674	62768	60571	61670	64342	62002	63172

Treatment	df	SED	F pr.
Folicur	93	1511.2	0.050
Variety	93	1511.2	<0.001
N management	93	1511.2	0.125
Nrate	93	2137.2	<0.001
Fol x Var	93	2137.2	0.668
Fol x Man	93	2137.2	0.925
Var x Man	93	2137.2	0.624
Fol x Nrate	93	3022.4	0.940
Var x Nrate	93	3022.4	0.538
Man x Nrate	93	3022.4	0.471
Fol x Var x Man	93	3022.4	0.832
Fol x Var x Nrate	93	4274.3	0.672
Fol x Man x Nrate	93	4274.3	0.973
Var x Man x Nrate	93	4274.3	0.988
Fol x Var x Man x Nrate	93	6044.8	0.975

† calculated from combine seed yield

Table 50. High Mowthorpe. Thousand seed weight.

Variety	N rate	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	0	6.05		6.05	6.00		6.00	6.03		6.03
Excalibur	120	5.61	5.62	5.62	5.64	5.55	5.60	5.62	5.59	5.61
Excalibur	240	5.34	5.59	5.47	5.39	5.43	5.41	5.36	5.51	5.44
Excalibur	360	5.28	5.16	5.22	5.65	5.37	5.51	5.47	5.27	5.37
Excalibur	Mean	5.57	5.61	5.59	5.67	5.59	5.63	5.62	5.60	5.61
PR45D03	0	5.87		5.87	5.72		5.72	5.80		5.80
PR45D03	120	5.46	5.45	5.46	5.43	5.46	5.44	5.44	5.46	5.45
PR45D03	240	5.41	5.21	5.31	5.30	5.31	5.30	5.35	5.26	5.31
PR45D03	360	5.31	5.29	5.30	5.34	5.42	5.38	5.32	5.36	5.34
PR45D03	Mean	5.51	5.46	5.49	5.45	5.48	5.46	5.48	5.47	5.47
Exc+D03	0	5.96		5.96	5.86		5.86	5.91		5.91
Exc+D03	120	5.53	5.54	5.54	5.53	5.50	5.52	5.53	5.52	5.53
Exc+D03	240	5.37	5.40	5.39	5.34	5.37	5.36	5.36	5.39	5.37
Exc+D03	360	5.30	5.23	5.26	5.50	5.40	5.45	5.40	5.31	5.35
Exc+D03	Mean	5.54	5.53	5.54	5.56	5.53	5.55	5.55	5.53	5.54

Treatment	df	SED	F pr.
Folicur	93	0.0400	0.818
Variety	93	0.0400	0.001
N management	93	0.0400	0.661
Nrate	93	0.0565	<0.001
Fol x Var	93	0.0565	0.421
Fol x Man	93	0.0565	0.827
Var x Man	93	0.0565	0.889
Fol x Nrate	93	0.0799	0.075
Var x Nrate	93	0.0799	0.367
Man x Nrate	93	0.0799	0.791
Fol x Var x Man	93	0.0799	0.196
Fol x Var x Nrate	93	0.1130	0.683
Fol x Man x Nrate	93	0.1130	0.997
Var x Man x Nrate	93	0.1130	0.211
Fol x Var x Man x Nrate	93	0.1599	0.814

Table 51. High Mowthorpe. seeds/m^2.

Variety	N rate kg/ha	No Folicur Conv	No Folicur CM	No Folicur Mean	Folicur (0.5 l/ha) Conv	Folicur (0.5 l/ha) CM	Folicur (0.5 l/ha) Mean	Conv Mean	CM Mean	Grand Mean
Excalibur	0	37066		37066	37378		37378	37222		37222
Excalibur	120	70851	67710	69281	68598	69725	67498	69725	67498	68611
Excalibur	240	87503	77018	82260	87279	87391	82180	87391	82180	84786
Excalibur	360	89671	86872	88271	83493	86582	86503	86582	86503	86542
Excalibur	Mean	71273	67166	69220	69187	70230	68351	70230	68351	69290
PR45D03	0	33185		33185	35773		35773	34479		34479
PR45D03	120	70541	64537	67539	67083	65669	66376	68812	65103	66958
PR45D03	240	75599	79460	77529	77565	78936	78251	76582	79198	77890
PR45D03	360	83478	84262	83870	83751	84380	84066	83615	84321	83968
PR45D03	Mean	65701	65361	65531	66043	66190	66116	65872	65775	65824
Exc+D03	0	35126		35126	36575		36575	35850		35850
Exc+D03	120	70696	66124	68410	67841	66478	67159	69268	66301	67784
Exc+D03	240	81551	78239	79895	82422	83140	82781	81987	80689	81338
Exc+D03	360	86575	85567	86071	83622	85257	84439	85098	85412	85255
Exc+D03	Mean	68487	66264	67375	67615	67862	67739	68051	67063	67557

Treatment	df	SED	F pr.
Folicur	93	847.2	0.669
Variety	93	847.2	<0.001
N management	93	847.2	0.247
Nrate	93	1198.1	<0.001
Fol x Var	93	1198.1	0.794
Fol x Man	93	1198.1	0.148
Var x Man	93	1198.1	0.296
Fol x Nrate	93	1694.3	0.185
Var x Nrate	93	1694.3	0.135
Man x Nrate	93	1694.3	0.510
Fol x Var x Man	93	1694.3	0.245
Fol x Var x Nrate	93	2396.1	0.370
Fol x Man x Nrate	93	2396.1	0.851
Var x Man x Nrate	93	2396.1	0.222
Fol x Var x Man x Nrate	93	3388.6	0.370

Table 52. Rosemaund. Thousand seed weight.

Variety	N rate kg/ha	No Folicur Conv	No Folicur CM	No Folicur Mean	Folicur (0.5 l/ha) Conv	Folicur (0.5 l/ha) CM	Folicur (0.5 l/ha) Mean	Conv Mean	CM Mean	Grand Mean
Excalibur	0	5.78		5.78	5.77		5.77	5.78		5.78
Excalibur	120	5.76	5.85	5.80	5.75	5.79	5.77	5.75	5.82	5.79
Excalibur	240	6.02	6.11	6.06	6.23	6.20	6.21	6.13	6.15	6.14
Excalibur	360	6.23	6.21	6.22	6.21	6.42	6.32	6.22	6.32	6.27
Excalibur	Mean	5.95	5.99	5.97	5.99	6.05	6.02	5.97	6.02	5.99
PR45D03	0	5.38		5.38	5.56		5.56	5.47		5.47
PR45D03	120	5.26	5.27	5.26	5.37	5.27	5.32	5.31	5.27	5.29
PR45D03	240	5.83	5.62	5.72	5.71	5.88	5.79	5.77	5.75	5.76
PR45D03	360	5.86	6.11	5.98	5.59	5.85	5.72	5.72	5.98	5.85
PR45D03	Mean	5.58	5.59	5.59	5.56	5.64	5.60	5.57	5.62	5.59
Exc+D03	0	5.58		5.58	5.67		5.67	5.62		5.62
Exc+D03	120	5.51	5.56	5.53	5.56	5.53	5.55	5.53	5.55	5.54
Exc+D03	240	5.93	5.86	5.89	5.97	6.04	6.00	5.95	5.95	5.95
Exc+D03	360	6.05	6.16	6.10	5.90	6.14	6.02	5.97	6.15	6.06
Exc+D03	Mean	5.77	5.79	5.78	5.77	5.84	5.81	5.77	5.82	5.79

Treatment	df	SED	F pr.
Folicur	93	0.0506	0.548
Variety	93	0.0506	<0.001
N management	93	0.0506	0.350
Nrate	93	0.0715	<0.001
Fol x Var	93	0.0715	0.704
Fol x Man	93	0.0715	0.646
Var x Man	93	0.0715	0.985
Fol x Nrate	93	0.1011	0.541
Var x Nrate	93	0.1011	0.612
Man x Nrate	93	0.1011	0.541
Fol x Var x Man	93	0.1011	0.775
Fol x Var x Nrate	93	0.1430	0.244
Fol x Man x Nrate	93	0.1430	0.861
Var x Man x Nrate	93	0.1430	0.800
Fol x Var x Man x Nrate	93	0.2023	0.601

Table 53. Rosemaund. seeds/m^2 (calculated from thousand seed weight and combine seed yield).

Variety	N rate kg/ha	No Folicur Conv	No Folicur CM	No Folicur Mean	Folicur (0.5 l/ha) Conv	Folicur (0.5 l/ha) CM	Folicur (0.5 l/ha) Mean	Conv Mean	CM Mean	Grand Mean
Excalibur	0	47961		47961	44793		44793	46377		46377
Excalibur	120	84461	82952	83707	79412	77033	78222	81936	79993	80964
Excalibur	240	85905	84995	85450	82301	83671	82986	84103	84333	84218
Excalibur	360	87312	90038	88675	82907	82413	82660	85109	86226	85667
Excalibur	Mean	76410	76487	76448	72353	71977	72165	74381	74232	74307
PR45D03	0	56318		56318	46863		46863	51590		51590
PR45D03	120	95869	94413	95141	85133	89819	87476	90501	92116	91308
PR45D03	240	95624	97465	96544	89548	87820	88684	92586	92643	92614
PR45D03	360	98176	95528	96852	94295	86248	90271	96235	90888	93562
PR45D03	Mean	86497	85931	86214	78960	77688	78324	82728	81809	82269
Exc+D03	0	52139		52139	43282		43282	47711		47711
Exc+D03	120	90165	88683	89424	77702	78791	78246	83933	83737	83835
Exc+D03	240	90764	91230	90997	81151	80982	81066	85958	86106	86032
Exc+D03	360	92744	92783	92764	83679	79645	81662	88211	86214	87213
Exc+D03	Mean	81453	81209	81331	71453	70675	71064	76453	75942	76198

Treatment	df	SED	F pr.
Folicur	93	1255.2	<0.001
Variety	93	1255.2	<0.001
N management	93	1255.2	0.671
Nrate	93	1775.1	<0.001
Fol x Var	93	1775.1	0.154
Fol x Man	93	1775.1	0.818
Var x Man	93	1775.1	0.760
Fol x Nrate	93	2510.4	0.979
Var x Nrate	93	2510.4	0.549
Man x Nrate	93	2510.4	0.910
Fol x Var x Man	93	2510.4	0.960
Fol x Var x Nrate	93	3550.2	0.835
Fol x Man x Nrate	93	3550.2	0.807
Var x Man x Nrate	93	3550.2	0.561
Fol x Var x Man x Nrate	93	5020.8	0.832

3.3.2. Experiment Year 2 – 2009/10

Soil and crop N in February

Experiments were drilled near ADAS Terrington (Norfolk) on 25/08/09, at Thornholme (E. Yorkshire), about 20 miles from High Mowthorpe, on 11/09/09 and ADAS Rosemaund (Herefordshire) on 31/08/09. The soil mineral N and GAI of the experimental crops was measured in late January or early February. A summary of this information (Table 54) shows that the combined supply of N from the crop and soil in February was 31 kg N/ha at Terrington, 68 kg N/ha at Rosemaund and 87 kg N/ha at Thornholme.

Table 54. Fertiliser requirement for canopy managed treatments

	Terrington	Thornholme	Rosemaund
SMN (kg/ha)	18	38	14
AAN (kg/ha)	31	59	25
GAI	0.24	0.9	1.12
Crop N (kg/ha)	13	49	54
SNS (kg/ha)	31	87	68
Fert N for GAI 3.5	240	147	178

SMN – soil mineral nitrogen

AAN – Additionally available N through mineralisation after February

SNS – soil nitrogen supply - sum of SMN and crop N

GAI – green area index

N treatments

The amount of fertiliser N required to achieve the optimum GAI of 3.5 by flowering was calculated at 240 kg/ha at Terrington, 178 kg/ha at Rosemaund and 147 kg/ha at Thornholme based on the measurements of soil and crop N. At all the sites it was estimated that the crop would not be able to take up all of the N required to acheve the optimum sized canopy by mid-flowering if the N applications were delayed until the 2nd conventional split timing (GS3,3 to 3,5). Therefore, 60 kg N/ha was applied at the 1st conventional split timing at Terrington and 40 kg N/ha was applied at the 1st conventional split timing at Rosemaund and Thornholme. After sufficient N had been applied to achieve the optimum GAI of 3.5 the remainder of the N was applied between yellow bud and early/mid flowering in late April/early May. The N applications in each split are described in Tables 55 to 57. The dates of the N applications andFolicur treatment are described in Table 58.

Table 55. Terrington N applications (kg/ha)

N treatment	Management	1st split	2nd split	3rd split	Total
1		0	0	0	0
2	Conventional	35	35	0	70
3	Conventional	70	70	0	140
4	Conventional	105	105	0	210
5	Conventional	140	140	0	280
6	Conventional	175	175	0	350
7	Managed	60	10	0	70
8	Managed	60	80	0	140
9	Managed	60	150	0	210
10	Managed	60	180	40	280
11	Managed	60	180	110	350

Table 56. Thornholme N applications (kg/ha)

N treatment	Management	1st split	2nd split	3rd split	Total
1		0	0	0	0
2	Conventional	30	30	0	60
3	Conventional	60	60	0	120
4	Conventional	90	90	0	180
5	Conventional	120	120	0	240
6	Conventional	150	150	0	300
7	Managed	40	20	0	60
8	Managed	40	80	0	120
9	Managed	40	110	30	180
10	Managed	40	110	90	240
11	Managed	40	110	150	300

Table 57. Rosemaund N applications (kg/ha)

N treatment	Management	1st split	2nd split	3rd split	Total
1		0	0	0	0
2	Conventional	30	30	0	60
3	Conventional	60	60	0	120
4	Conventional	90	90	0	180
5	Conventional	120	120	0	240
6	Conventional	150	150	0	300
7	Managed	40	20	0	60
8	Managed	40	80	0	120
9	Managed	40	140	0	180
10	Managed	40	140	60	240
11	Managed	40	140	120	300

Table 58. Timings of Nitrogen and Folicur treatments

	Terrington	High Mowthorpe	Rosemaund
1st N timing	10/03/10	10/03/10	25/02/10
2nd N timing	09/04/10	13/04/10	23/03/10
3rd N timing	21/04/10	06/05/10	10/04/10
Folicur timing	24/04/10	21/04/10	9/04/10
	(0.5 l/ha)	(0.5 l/ha)	(1.0 l/ha)

Seed yield

At Terrington, nitrogen rate and Folicur treatment significantly affected yield, with Folicur application increasing yield by an average of 0.22 t/ha (Table 59). Averaged over all treatments, yields significantly increased with each level of N from nil N (1.71 t/ha) to 210 kg N/ha (3.59 t/ha). There were no significant effects of variety or Canopy Management.

At Thornholme, nitrogen rate and Folicur treatment significantly affected yield, with Folicur application increasing the yield of Excalibur by 0.27 t/ha, compared to no response in PR45D03. Averaged over all treatments, yields significantly increased with each level of N from nil N (3.52 t/ha) to 300 kg N/ha (5.23 t/ha), except from the step from 180 to 240 kg N/ha, which was not significant. There were no significant effects of variety alone, or Canopy Management.

At Rosemaund, as at both other sites, nitrogen rate and Folicur treatment significantly affected yield, with Folicur application increasing yield by an average of 0.68 t/ha (Table 61). Averaged over all treatments, yields significantly increased with each level of N from nil N (3.54 t/ha) to 180 kg N/ha (5.28 t/ha). There were no significant effects of variety or Canopy Management.

Table 59. Terrington seed yields (t/ha @ 91% DM).

Variety	N rate kg/ha	No Folicur Conv	No Folicur CM	No Folicur Mean	Folicur (0.5 l/ha) Conv	Folicur (0.5 l/ha) CM	Folicur (0.5 l/ha) Mean	Conv Mean	CM Mean	Grand Mean
Excalibur	0	1.53		1.53	1.66		1.66	1.60		1.60
Excalibur	70	2.43	2.54	2.49	2.41	2.43	2.42	2.42	2.49	2.45
Excalibur	140	3.08	3.20	3.14	3.50	3.42	3.46	3.29	3.31	3.30
Excalibur	210	3.36	3.36	3.36	3.63	3.68	3.66	3.50	3.52	3.51
Excalibur	280	3.48	3.41	3.45	4.02	3.98	4.00	3.75	3.70	3.72
Excalibur	350	3.67	3.54	3.60	3.88	3.78	3.83	3.78	3.66	3.72
Excalibur	Mean	2.92	2.93	2.93	3.18	3.16	3.17	3.05	3.05	3.05
PR45D03	0	1.80		1.80	1.85		1.85	1.83		1.83
PR45D03	70	2.46	2.74	2.60	2.69	2.73	2.71	2.58	2.74	2.66
PR45D03	140	3.26	3.38	3.32	3.32	3.46	3.39	3.29	3.42	3.35
PR45D03	210	3.35	3.49	3.42	3.81	4.01	3.91	3.58	3.75	3.67
PR45D03	280	3.25	3.47	3.36	3.60	4.01	3.81	3.42	3.74	3.58
PR45D03	350	3.64	3.68	3.66	3.76	3.62	3.69	3.70	3.65	3.68
PR45D03	Mean	2.96	3.09	3.03	3.17	3.28	3.23	3.07	3.19	3.13
Exc+D03	0	1.67		1.67	1.76		1.76	1.71		1.71
Exc+D03	70	2.44	2.64	2.54	2.55	2.58	2.57	2.50	2.61	2.55
Exc+D03	140	3.17	3.29	3.23	3.41	3.44	3.43	3.29	3.36	3.33
Exc+D03	210	3.36	3.42	3.39	3.72	3.85	3.78	3.54	3.64	3.59
Exc+D03	280	3.36	3.44	3.40	3.81	4.00	3.90	3.58	3.72	3.65
Exc+D03	350	3.65	3.61	3.63	3.82	3.70	3.76	3.74	3.65	3.70
Exc+D03	Mean	2.94	3.01	2.98	3.18	3.22	3.20	3.06	3.12	3.09

Treatment	df	SED	F pr.
Folicur	141	0.0565	<0.001
Variety	141	0.0565	0.175
N management	141	0.0565	0.321
N rate	141	0.0978	<0.001
Fol x Var	141	0.0799	0.703
Fol x Man	141	0.0799	0.805
Var x Man	141	0.0799	0.252
Fol x Nrate	141	0.1383	0.116
Var x Nrate	141	0.1383	0.353
Man x Nrate	141	0.1383	0.876
Fol x Var x Man	141	0.1129	0.977
Fol x Var x Nrate	141	0.1956	0.796
Fol x Man x Nrate	141	0.1956	0.983
Var x Man x Nrate	141	0.1956	0.958
Fol x Var x Man x Nrate	141	0.2767	0.993

Table 60. Thornholme seed yields (t/ha @ 91% DM).

Variety	N rate kg/ha	No Folicur Conv	No Folicur CM	No Folicur Mean	Folicur (0.5 l/ha) Conv	Folicur (0.5 l/ha) CM	Folicur (0.5 l/ha) Mean	Conv Mean	CM Mean	Grand Mean
Excalibur	0	3.19		3.19	3.72		3.72	3.46		3.46
Excalibur	60	4.39	4.23	4.31	4.20	4.23	4.22	4.30	4.23	4.26
Excalibur	120	4.53	4.45	4.49	4.79	4.84	4.81	4.66	4.64	4.65
Excalibur	180	5.03	4.76	4.89	5.08	5.10	5.09	5.05	4.93	4.99
Excalibur	240	5.02	4.75	4.88	5.44	5.28	5.36	5.23	5.01	5.12
Excalibur	300	5.19	5.16	5.17	5.44	5.30	5.37	5.32	5.23	5.27
Excalibur	Mean	4.56	4.42	4.49	4.78	4.75	4.76	4.67	4.59	4.63
PR45D03	0	3.49		3.49	3.67		3.67	3.58		3.58
PR45D03	60	4.28	4.34	4.31	4.21	4.23	4.22	4.24	4.29	4.26
PR45D03	120	4.85	4.69	4.77	4.34	4.70	4.52	4.60	4.70	4.65
PR45D03	180	4.94	5.25	5.10	5.04	4.95	5.00	4.99	5.10	5.05
PR45D03	240	4.69	4.93	4.81	4.96	5.15	5.06	4.83	5.04	4.93
PR45D03	300	5.20	5.17	5.19	5.09	5.25	5.17	5.15	5.21	5.18
PR45D03	Mean	4.58	4.65	4.61	4.55	4.66	4.61	4.56	4.65	4.61
Exc+D03	0	3.34		3.34	3.70		3.70	3.52		3.52
Exc+D03	60	4.34	4.29	4.31	4.20	4.23	4.22	4.27	4.26	4.26
Exc+D03	120	4.69	4.57	4.63	4.57	4.77	4.67	4.63	4.67	4.65
Exc+D03	180	4.98	5.00	4.99	5.06	5.03	5.04	5.02	5.02	5.02
Exc+D03	240	4.85	4.84	4.85	5.20	5.21	5.21	5.03	5.03	5.03
Exc+D03	300	5.19	5.16	5.18	5.27	5.28	5.27	5.23	5.22	5.23
Exc+D03	Mean	4.57	4.53	4.55	4.67	4.70	4.68	4.62	4.62	4.62

Treatment	df	SED	F pr.
Folicur	141	0.0549	0.016
Variety	141	0.0549	0.742
N management	141	0.0549	0.955
N rate	141	0.0951	<0.001
Fol x Var	141	0.0777	0.013
Fol x Man	141	0.0777	0.525
Var x Man	141	0.0777	0.121
Fol x Nrate	141	0.1345	0.100
Var x Nrate	141	0.1345	0.652
Man x Nrate	141	0.1345	1.000
Fol x Var x Man	141	0.1098	0.758
Fol x Var x Nrate	141	0.1902	0.786
Fol x Man x Nrate	141	0.1902	0.941
Var x Man x Nrate	141	0.1902	0.917
Fol x Var x Man x Nrate	141	0.269	0.743

Table 61. Rosemaund seed yields (t/ha @ 91% DM).

Variety	N rate kg/ha	No Folicur Conv	No Folicur CM	No Folicur Mean	Folicur 1.0 l/ha) Conv	Folicur 1.0 l/ha) CM	Folicur 1.0 l/ha) Mean	Conv Mean	CM Mean	Grand Mean
Excalibur	0	3.46		3.46	3.89		3.89	3.71		3.71
Excalibur	60	4.57	4.58	4.58	5.05	5.06	5.06	4.89	4.82	4.85
Excalibur	120	4.62	4.63	4.63	5.27	5.27	5.27	4.95	4.95	4.95
Excalibur	180	4.08	5.26	4.76	5.20	5.85	5.52	4.72	5.56	5.17
Excalibur	240	4.78	4.74	4.76	5.87	5.73	5.80	5.40	5.23	5.31
Excalibur	300	5.04	5.06	5.05	5.78	5.69	5.73	5.41	5.38	5.39
Excalibur	Mean	4.46	4.67	4.58	5.18	5.25	5.21	4.86	4.97	4.92
PR45D03	0	3.29		3.29	3.51		3.51	3.40		3.40
PR45D03	60	4.19	4.20	4.20	4.41	4.91	4.66	4.30	4.56	4.43
PR45D03	120	4.67	4.32	4.50	5.47	5.16	5.32	5.07	4.74	4.91
PR45D03	180	5.02	4.93	4.98	5.83	5.78	5.81	5.43	5.35	5.39
PR45D03	240	4.99	4.95	4.97	5.77	5.80	5.78	5.38	5.44	5.40
PR45D03	300	4.97	4.79	4.88	5.96	5.72	5.84	5.47	5.25	5.36
PR45D03	Mean	4.52	4.39	4.46	5.16	5.15	5.15	4.84	4.78	4.81
Exc+D03	0	3.36		3.36	3.70		3.70	3.54		3.54
Exc+D03	60	4.32	4.39	4.36	4.73	4.99	4.86	4.55	4.69	4.63
Exc+D03	120	4.65	4.48	4.56	5.37	5.21	5.29	5.01	4.85	4.93
Exc+D03	180	4.62	5.10	4.87	5.52	5.81	5.66	5.10	5.46	5.28
Exc+D03	240	4.90	4.83	4.86	5.82	5.76	5.79	5.39	5.33	5.36
Exc+D03	300	5.01	4.93	4.97	5.87	5.70	5.78	5.44	5.31	5.38
Exc+D03	Mean	4.50	4.53	4.51	5.17	5.20	5.18	4.85	4.87	4.86

Treatment	df	SED	F pr.
Folicur	134	0.0708	<0.001
Variety	134	0.0708	0.328
N management	134	0.0708	0.649
N rate	134	0.1226	<0.001
Fol x Var	134	0.1001	0.895
Fol x Man	134	0.1001	0.962
Var x Man	134	0.1001	0.174
Fol x Nrate	134	0.1734	0.068
Var x Nrate	134	0.1734	0.070
Man x Nrate	134	0.1734	0.218
Fol x Var x Man	134	0.1415	0.430
Fol x Var x Nrate	134	0.2452	0.920
Fol x Man x Nrate	134	0.2452	0.963
Var x Man x Nrate	134	0.2452	0.201
Fol x Var x Man x Nrate	134	0.3467	0.993

Optimum N rates

At Terrington, regression analyses showed that fitting parallel curves for each treatment combination accounted for the most variation between N rate and yield (79.2%, P=0.004). The economically optimum N rate was 228 kg N/ha for all treatments (Table 62).

At Thornholme, regression analyses showed that fitting parallel curves for each treatment combination accounted for the most variation between N rate and yield (71.9%, P=0.025). The economically optimum N rate was 215 kg N/ha for all treatments (Table 62).

At Rosemaund, regression analyses showed that fitting parallel curves for each treatment combination accounted for the most variation between N rate and yield (64.0%, P<0.001). The economically optimum N rate was 176 kg N/ha for all treatments (Table 62).

Table 62. Optimum N rate and yields at N opt.

	Terrington	Thornholme	Rosemaund
Economically optimum N rate (kg/ha)	228	215	176
Excalibur Conventional N timings	3.47	4.98	4.78
Excalibur Managed N timings	3.47	4.85	4.98
Excalibur Conventional N timings with Folicur	3.73	5.20	5.54
Excalibur Managed N timings with Folicur	3.70	5.17	5.61
PR45D03 Conventional N timings	3.50	5.00	4.89
PR45D03 Managed N timings	3.64	5.07	4.78
PR45D03 Conventional N timings with Folicur	3.72	4.98	5.52
PR45D03 Managed N timings with Folicur	3.83	5.08	5.51

Crop growth before stem extension

Crop assessments carried out in February before any N applications showed that the GAI, dry matter, N concentration and N content of the two varieties did not differ at any of the three sites (Table 63). Across both varieties, each unit of GAI contained 53.9 kg N/ha at Terrington, 54.0 kg N/ha at Thornholme and 48.6 kg N/ha at Rosemaund. These results support previous studies which have shown that oilseed rape crops contain about 50 kg N/ha per unit of GAI. At Rosemaund only there was a significant difference between the two varieties in crop kg N/ha per unit of GAI, with PR45D03 containing more N per unit GAI (Table 63).

Table 63. February measurements.

Terrington

	GAI	Dry matter (t/ha)	N content (% of dry matter)	Crop N (kg/ha)
Excalibur	0.260	0.46	2.96	13.6
PR45D03	0.223	0.43	2.86	12.5
Mean	0.242	0.45	2.91	13.0
SED (3 df)	0.0402	0.0698	0.1995	2.60
F pr.	0.426	0.726	0.645	0.691

Thornholme

	GAI	Dry matter (t/ha)	N content (% of dry matter)	Crop N (kg/ha)
Excalibur	0.910	1.15	4.40	50.5
PR45D03	0.897	1.17	4.04	47.0
Mean	0.904	1.16	4.22	48.8
SED (3 df)	0.1404	0.2030	0.1142	7.79
F pr.	0.932	0.922	0.052	0.684

Rosemaund

	GAI	Dry matter (t/ha)	N content (% of dry matter)	Crop N (kg/ha)
Excalibur	1.229	1.65	3.11	51.5
PR45D03	1.010	1.70	3.34	57.3
Mean	1.119	1.68	3.23	54.4
SED (3 df)	0.0958	0.0746	0.1189	3.47
F pr.	0.107	0.532	0.142	0.193

GAI, dry weight and N content at mid-flowering

Increased N rates significantly increased the GAI of leaves and stems and the biomass and N content of all parts of the crop at all sites except Rosemaund, where flower and stem biomass were not significantly increased by the higher N rate (Table 64 to 72).

At Terrington, there were no significant effects of N management on GAI, biomass or crop N status at mid-flowering. The only significant effects of variety were on stem biomass, which was higher for Excalibur than for PR45D03 (Table 65), and the N concentration of stems and flowers, which was higher for PR45D03 (Table 70).

These differences balanced each other such that there was no difference between the varieties in whole crop N content.

The soil mineral N + crop N in February amounted to 31 kg N/ha at Terrington. In theory this would have been expected to be taken up into the crop by mid-flowering and to produce a GAI of 0.62 in control plots. The measurements at Nil N showed that the crop had taken up 59 kg N/ha (Table 70) and achieved a GAI of 0.90 (Table 64). Applying 280 kg N/ha would be expected to increase N uptake by 168 kg N/ha and increase the GAI by 3.4 units. The measured increases were 86 kg N/ha and 1.42 GAI units. It is likely that the dry weather in spring reduced N uptake efficiency at this site.

At Thornholme, Conventional N timings gave a significantly higher leaf and total GAI at mid-flowering than Canopy Managed timings (Table 66), although even at the higher N rate of 240 kg N/ha, both management strategies gave a total GAI below the target of 3.5 units. Canopy Management did not significantly affect stem GAI or the biomass of any crop fraction (Table 67). Variety did not significantly affect total GAI or total biomass, but the biomass fractions, with PR45D03 having a lower stem biomass and higher flower and pod biomass than Excalibur. Excalibur also showed a slightly greater increase in stem biomass in response to higher N ($P < 0.1$). PR45D03 had a significantly higher N concentration than Excalibur in all plant parts but, due to its lower biomass than Excalibur, there was no difference in total crop N content between the varieties (Table 71).

The soil mineral N + crop N in February amounted to 87 kg N/ha at Thornholme. In theory this would have been expected to be taken up into the crop by mid-flowering and to produce a GAI of 1.74 in control plots. The measurements at Nil N showed that the crop had taken up 81 kg N/ha (Table 71) but only achieved a GAI of 1.05 (Table 66). Applying 240 kg N/ha would be expected to increase N uptake by 144 kg N/ha and increase the GAI by 2.9 units. The measured increases were 110 kg N/ha and 1.4 GAI units. Dry spring weather may have reduced N uptake efficiency at this site.

At Rosemaund Conventional N timings gave a higher stem biomass than Canopy Managed timings (Table 69), but did not have any other significant effects on GAI, biomass or plant N status. PR45D03 had a significantly higher leaf biomass but lower leaf GAI than Excalibur, and a lower stem and total biomass. PR45D03 also had a higher N concentration in the stems and flowers, as at both other sites (Table 72). There was no difference in total N uptake between the two varieties.

The soil mineral N + crop N in February amounted to 68 kg N/ha at Rosemaund. In theory this would have been expected to be taken up into the crop by mid-flowering and to produce a GAI of 1.36 in control plots. The measurements at Nil N showed that the crop had taken up 156 kg N/ha (Table 72) and achieved a GAI of 2.31 (Table 68). The N uptake in the Nil N plots was therefore much larger than expected which is difficult to explain given the dry conditions. Applying 240 kg N/ha would be expected to increase N uptake by 144 kg N/ha and increase the GAI by 2.9 units. The measured increases were 105 kg N/ha and 2.76 GAI units.

Across all the sites it was interesting to observe that the overall amount of N taken up by flowering and GAI did not differ between Excalibur and PR45D03. The overall biomass was only less for the semi-dwarf at one site only (Rosemaund). The semi-dwarf did have a consistently greater stem N% and consistently lower stem biomass and stem GAI.

Across all sites, a comparison of crop N content and GAI supported the ratio derived from previous work, that approximately 50 kg N/ha is required to build each unit of GAI. With the means of each variety-N rate-management combination from each site plotted together (Fig. 5.2), the regression equation gave an actual value of 58 kg N/ha for each unit GAI. There were no significant differences between the varieties or N management strategies in N content per unit GAI at any site (Tables 70 to 72), and although at Rosemaund the nil N treatment had significantly higher N content per unit GAI than the 240 N treatment, the same pattern did not occur at the other sites.

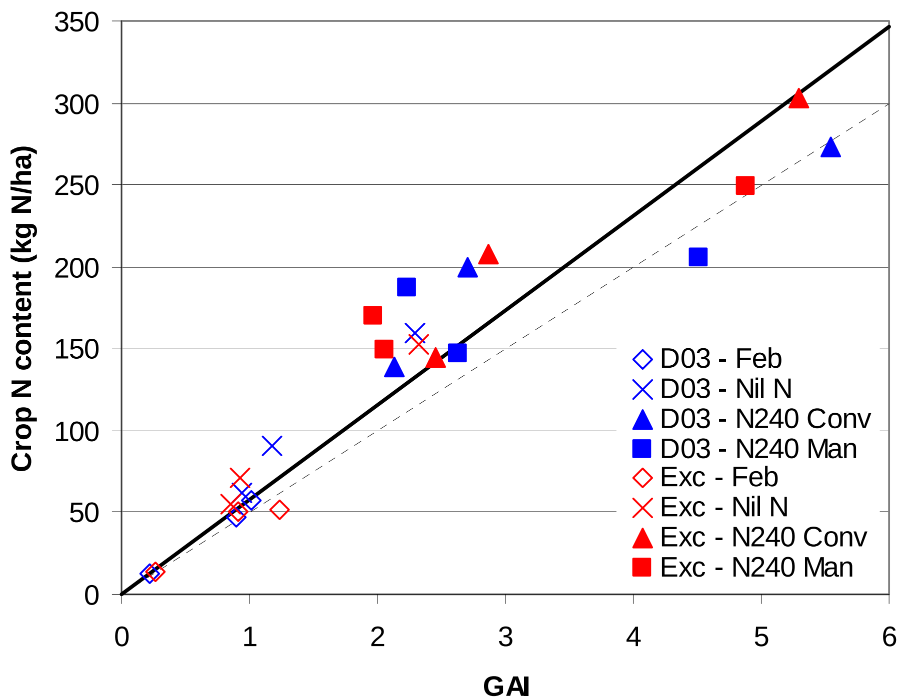


Figure 2. Comparison of GAI and crop N content, for all sites.

Table 64. Terrington. Mid flowering green area indices.

Variety	N rate kg/ha	GAI leaves			GAI stems			Total GAI		
		Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	0.61		0.61	0.24		0.24	0.85		0.85
Excalibur	280	1.98	1.62	1.80	0.48	0.44	0.46	2.46	2.06	2.26
Excalibur	Mean	1.29	1.11	1.20	0.36	0.34	0.35	1.66	1.45	1.55
PR45D03	0	0.69		0.69	0.25		0.25	0.94		0.94
PR45D03	280	1.78	2.29	2.03	0.36	0.34	0.35	2.13	2.63	2.38
PR45D03	Mean	1.23	1.49	1.36	0.31	0.30	0.30	1.54	1.79	1.66
Exc+D03	0	0.65		0.65	0.25		0.25	0.90		0.90
Exc+D03	280	1.88	1.95	1.92	0.42	0.39	0.41	2.30	2.35	2.32
Exc+D03	Mean	1.26	1.30	1.28	0.33	0.32	0.33	1.60	1.62	1.61
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		20	0.1673	0.356	21	0.0272	0.085	20	0.1907	0.583
N management		20	0.1673	0.827	21	0.0272	0.591	20	0.1907	0.899
Nrate		20	0.1673	<0.001	21	0.0272	<0.001	20	0.1907	<0.001
Var x Man		20	0.2366	0.207	21	0.0385	0.825	20	0.2697	0.249
Var x Nrate		20	0.2366	0.670	21	0.0385	0.038	20	0.2697	0.959
Man x Nrate		20	0.2366	0.827	21	0.0385	0.591	20	0.2697	0.899
Var x Man x Nrate		20	0.3346	0.207	21	0.0544	0.825	20	0.3814	0.249

Table 65. Terrington. Mid flowering dry matter measurements.

Variety	N rate	Leaf biomass (t/ha)			Stem biomass (t/ha)			Flower biomass (t/ha)			Total biomass (t/ha)		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	0.59		0.59	2.06		2.06	0.72		0.72	3.37		3.37
Excalibur	280	1.49	1.42	1.46	3.12	3.01	3.06	1.00	1.10	1.05	5.61	5.53	5.57
Excalibur	Mean	1.04	1.00	1.02	2.59	2.54	2.56	0.86	0.91	0.88	4.49	4.45	4.47
PR45D03	0	0.66		0.66	1.76		1.76	0.82		0.82	3.23		3.23
PR45D03	280	1.39	1.58	1.48	2.14	1.93	2.03	0.95	0.92	0.93	4.47	4.43	4.45
PR45D03	Mean	1.02	1.12	1.07	1.95	1.84	1.90	0.88	0.87	0.87	3.85	3.83	3.84
Exc+D03	0	0.62		0.62	1.91		1.91	0.77		0.77	3.30		3.30
Exc+D03	280	1.44	1.50	1.47	2.63	2.47	2.55	0.97	1.01	0.99	5.04	4.98	5.01
Exc+D03	Mean	1.03	1.06	1.05	2.27	2.19	2.23	0.87	0.89	0.88	4.17	4.14	4.16
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		21	0.1204	0.671	21	0.208	0.004	21	0.1002	0.925	21	0.413	0.145
N management		21	0.1204	0.806	21	0.208	0.705	21	0.1002	0.864	21	0.413	0.938
Nrate		21	0.1204	<0.001	21	0.208	0.006	21	0.1002	0.036	21	0.413	<0.001
Var x Man		21	0.1703	0.594	21	0.294	0.909	21	0.1417	0.772	21	0.585	0.978
Var x Nrate		21	0.1703	0.845	21	0.294	0.096	21	0.1417	0.302	21	0.585	0.248
Man x Nrate		21	0.1703	0.806	21	0.294	0.705	21	0.1417	0.864	21	0.585	0.938
Var x Man x Nrate		21	0.2409	0.594	21	0.416	0.909	21	0.2003	0.772	21	0.827	0.978

Table 66. Thornholme. Mid flowering green area indices.

Variety	N rate kg/ha	GAI leaves			GAI stems			Total GAI		
		Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	0.51		0.51	0.42		0.42	0.93		0.93
Excalibur	240	2.07	1.35	1.71	0.79	0.62	0.71	2.87	1.97	2.42
Excalibur	Mean	1.29	0.93	1.11	0.61	0.52	0.56	1.90	1.45	1.68
PR45D03	0	0.73		0.73	0.45		0.45	1.18		1.18
PR45D03	240	2.10	1.61	1.86	0.61	0.62	0.61	2.71	2.23	2.47
PR45D03	Mean	1.41	1.17	1.29	0.53	0.53	0.53	1.94	1.70	1.82
Exc+D03	0	0.62		0.62	0.44		0.44	1.05		1.05
Exc+D03	240	2.09	1.48	1.78	0.70	0.62	0.66	2.79	2.10	2.44
Exc+D03	Mean	1.35	1.05	1.20	0.57	0.53	0.55	1.92	1.58	1.75
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		21	0.1078	0.107	21	0.0341	0.321	21	0.1357	0.291
N management		21	0.1078	0.011	21	0.0341	0.232	21	0.1357	0.019
Nrate		21	0.1078	<0.001	21	0.0341	<0.001	21	0.1357	<0.001
Var x Man		21	0.1524	0.591	21	0.0482	0.197	21	0.1919	0.451
Var x Nrate		21	0.1524	0.745	21	0.0482	0.088	21	0.1919	0.485
Man x Nrate		21	0.1524	0.011	21	0.0482	0.232	21	0.1919	0.019
Var x Man x Nrate		21	0.2155	0.591	21	0.0682	0.197	21	0.2714	0.451

Table 67. Thornholme. Mid flowering dry matter measurements.

Variety	N rate kg/ha	Leaf biomass (t/ha)			Stem biomass (t/ha)			Flower and pod biomass (t/ha)			Total biomass (t/ha)		
		Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	0.58		0.58	3.36		3.36	0.63		0.63	4.57		4.57
Excalibur	240	1.58	1.31	1.44	5.57	3.92	4.74	1.14	0.94	1.04	8.29	6.16	7.23
Excalibur	Mean	1.08	0.94	1.01	4.47	3.64	4.05	0.89	0.78	0.84	6.43	5.37	5.90
PR45D03	0	0.76		0.76	3.29		3.29	0.92		0.92	4.97		4.97
PR45D03	240	1.50	1.32	1.41	3.65	3.74	3.69	1.20	1.20	1.20	6.35	6.26	6.30
PR45D03	Mean	1.13	1.04	1.09	3.47	3.51	3.49	1.06	1.06	1.06	5.66	5.61	5.64
Exc+D03	0	0.67		0.67	3.33		3.33	0.77		0.77	4.77		4.77
Exc+D03	240	1.54	1.31	1.43	4.61	3.83	4.22	1.17	1.07	1.12	7.32	6.21	6.76
Exc+D03	Mean	1.11	0.99	1.05	3.97	3.58	3.77	0.97	0.92	0.95	6.05	5.49	5.77
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		21	0.0669	0.268	21	0.259	0.042	21	0.0536	<0.001	21	0.364	0.478
N management		21	0.0669	0.102	21	0.259	0.147	21	0.0536	0.349	21	0.364	0.141
Nrate		21	0.0669	<0.001	21	0.259	0.002	21	0.0536	<0.001	21	0.364	<0.001
Var x Man		21	0.0946	0.746	21	0.367	0.108	21	0.0758	0.351	21	0.514	0.176
Var x Nrate		21	0.0946	0.117	21	0.367	0.073	21	0.0758	0.263	21	0.514	0.083
Man x Nrate		21	0.0946	0.102	21	0.367	0.147	21	0.0758	0.349	21	0.514	0.141
Var x Man x Nrate		21	0.1338	0.746	21	0.519	0.108	21	0.1071	0.351	21	0.727	0.176

Table 68. Rosemaund. Mid flowering green area indices.

Variety	N rate kg/ha	GAI leaves Conv	CM	Mean	GAI stems Conv	CM	Mean	Total GAI Conv	CM	Mean
Excalibur	0	1.57		1.57	0.76		0.76	2.33		2.33
Excalibur	240	4.10	3.97	4.04	1.19	0.90	1.05	5.29	4.88	5.08
Excalibur	Mean	2.83	2.77	2.80	0.98	0.83	0.90	3.81	3.60	3.71
PR45D03	0	1.69		1.69	0.60		0.60	2.29		2.29
PR45D03	240	4.81	3.87	4.34	0.80	0.65	0.72	5.60	4.52	5.06
PR45D03	Mean	3.25	2.78	3.01	0.70	0.63	0.66	3.95	3.41	3.68
Exc+D03	0	1.63		1.63	0.68		0.68	2.31		2.31
Exc+D03	240	4.45	3.92	4.19	0.99	0.78	0.89	5.45	4.70	5.07
Exc+D03	Mean	3.04	2.78	2.91	0.84	0.73	0.78	3.88	3.51	3.69
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		20	0.266	0.435	20	0.0469	<0.001	20	0.300	0.925
N management		20	0.266	0.332	20	0.0469	0.032	20	0.300	0.228
Nrate		20	0.266	<0.001	20	0.0469	<0.001	20	0.300	<0.001
Var x Man		20	0.376	0.454	20	0.0664	0.449	20	0.424	0.584
Var x Nrate		20	0.376	0.730	20	0.0664	0.089	20	0.424	0.976
Man x Nrate		20	0.376	0.332	20	0.0664	0.032	20	0.424	0.228
Var x Man x Nrate		20	0.532	0.454	20	0.0939	0.449	20	0.599	0.584

Table 69. Rosemaund. Mid flowering dry matter measurements.

Variety	N rate kg/ha	Leaf biomass (t/ha) Conv	CM	Mean	Stem biomass (t/ha) Conv	CM	Mean	Flower biomass (t/ha) Conv	CM	Mean	Total biomass (t/ha) Conv	CM	Mean
Excalibur	0	1.03		1.03	5.11		5.11	0.77		0.77	6.91		6.91
Excalibur	240	1.54	1.67	1.61	6.89	5.19	6.04	0.81	0.78	0.79	9.24	7.64	8.44
Excalibur	Mean	1.29	1.35	1.32	6.00	5.15	5.57	0.79	0.77	0.78	8.07	7.27	7.67
PR45D03	0	1.31		1.31	3.89		3.89	0.82		0.82	6.03		6.03
PR45D03	240	2.20	1.75	1.98	4.43	3.93	4.18	0.74	0.75	0.74	7.37	6.43	6.90
PR45D03	Mean	1.76	1.53	1.64	4.16	3.91	4.04	0.78	0.78	0.78	6.70	6.23	6.46
Exc+D03	0	1.17		1.17	4.50		4.50	0.80		0.80	6.47		6.47
Exc+D03	240	1.87	1.71	1.79	5.66	4.56	5.11	0.73	0.76	0.77	8.31	7.03	7.67
Exc+D03	Mean	1.52	1.44	1.48	5.08	4.53	4.80	0.79	0.78	0.78	7.39	6.75	7.07
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		20	0.1288	0.020	20	0.385	<0.001	20	0.070	0.969	20	0.528	0.033
N management		20	0.1288	0.532	20	0.385	0.169	20	0.070	0.938	20	0.528	0.242
Nrate		20	0.1288	<0.001	20	0.385	0.127	20	0.070	0.678	20	0.528	0.034
Var x Man		20	0.1821	0.276	20	0.544	0.445	20	0.099	0.900	20	0.747	0.759
Var x Nrate		20	0.1821	0.743	20	0.544	0.412	20	0.099	0.472	20	0.747	0.538
Man x Nrate		20	0.1821	0.532	20	0.544	0.169	20	0.099	0.938	20	0.747	0.242
Var x Man x Nrate		20	0.2575	0.276	20	0.770	0.445	20	0.139	0.900	20	1.056	0.759

Table 70. Terrington. Mid flowering measurement of nitrogen concentration in dry plant material on Treatments 1, 3 and 9 without Folicur.

Variety	N rate	Leaf N%			Other plant material N %			Total crop N (kg/ha)			Crop N (kg N/ha) per unit GAI		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	2.37		2.37	1.49		1.49	55.5		55.5	66.8		66.8
Excalibur	280	3.75	3.83	3.79	2.15	2.38	2.26	144.1	149.2	146.6	59.2	72.5	65.8
Excalibur	Mean	3.06	3.10	3.08	1.82	1.94	1.88	99.8	102.4	101.1	63.0	69.6	66.3
PR45D03	0	2.23		2.23	1.84		1.84	61.5		61.5	66.3		66.3
PR45D03	280	3.96	4.37	4.16	2.73	2.74	2.74	139.0	146.9	143.0	66.8	57.1	61.9
PR45D03	Mean	3.09	3.30	3.20	2.29	2.29	2.29	100.3	104.2	102.3	66.5	61.7	64.1
Exc+D03	0	2.30		2.30	1.67		1.67	58.5		58.5	66.5		66.5
Exc+D03	280	3.86	4.10	3.98	2.44	2.56	2.50	141.6	148.1	144.8	63.0	64.8	63.9
Exc+D03	Mean	3.08	3.20	3.14	2.05	2.11	2.08	100.0	103.3	101.7	64.8	65.7	65.2
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		21	0.1058	0.295	21	0.0789	<0.001	21	9.44	0.903	20	2.89	0.458
N management		21	0.1058	0.266	21	0.0789	0.467	21	9.44	0.734	20	2.89	0.757
Nrate		21	0.1058	<.001	21	0.0789	<0.001	21	9.44	<0.001	20	2.89	0.365
Var x Man		21	0.1497	0.446	21	0.1116	0.474	21	13.35	0.944	20	4.08	0.061
Var x Nrate		21	0.1497	0.023	21	0.1116	0.446	21	13.35	0.614	20	4.08	0.562
Man x Nrate		21	0.1497	0.266	21	0.1116	0.467	21	13.35	0.734	20	4.08	0.757
Var x Man x Nrate		21	0.2116	0.446	21	0.1578	0.474	21	18.88	0.944	20	5.77	0.061

Table 71. Thornholme. Mid flowering measurement of nitrogen concentration in dry plant material on Treatments 1, 3 and 9 without Folicur.

Variety	N rate	Leaf N%			Other plant material N %			Total crop N (kg/ha)			Crop N (kg N/ha) per unit GAI		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	2.48		2.48	1.39		1.39	70.6		70.6	74.2		74.2
Excalibur	240	4.18	4.14	4.16	2.07	2.38	2.22	208.1	169.7	188.9	72.8	88.7	80.8
Excalibur	Mean	3.33	3.31	3.32	1.73	1.88	1.80	139.3	120.1	129.7	73.5	81.5	77.5
PR45D03	0	2.63		2.63	1.66		1.66	91.2		91.2	77.7		77.7
PR45D03	240	4.54	4.50	4.52	2.67	2.60	2.64	199.7	187.6	193.6	74.2	84.4	79.3
PR45D03	Mean	3.58	3.56	3.57	2.17	2.13	2.15	145.4	139.4	142.4	76.0	81.0	78.5
Exc+D03	0	2.56		2.56	1.52		1.52	80.9		80.9	76.0		76.0
Exc+D03	240	4.36	4.32	4.34	2.37	2.49	2.43	203.9	178.6	191.3	73.5	86.6	80.0
Exc+D03	Mean	3.46	3.44	3.45	1.95	2.01	1.98	142.4	129.8	136.1	74.7	81.3	78.0
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		21	0.0888	0.010	21	0.0903	0.001	21	10.99	0.261	21	3.25	0.760
N management		21	0.0888	0.826	21	0.0903	0.517	21	10.99	0.263	21	3.25	0.057
Nrate		21	0.0888	<0.001	21	0.0903	<0.001	21	10.99	<0.001	21	3.25	0.224
Var x Man		21	0.1256	0.999	21	0.1277	0.305	21	15.54	0.555	21	4.59	0.658
Var x Nrate		21	0.1256	0.246	21	0.1277	0.432	21	15.54	0.476	21	4.59	0.454
Man x Nrate		21	0.1256	0.826	21	0.1277	0.517	21	15.54	0.263	21	4.59	0.057
Var x Man x Nrate		21	0.1776	0.999	21	0.1807	0.305	21	21.97	0.555	21	6.49	0.658

Table 72. Rosemaund. Mid flowering measurement of nitrogen concentration in dry plant material on Treatments 1, 3 and 9 without Folicur.

Variety	N rate	Leaf N%			Other plant material N %			Total crop N (kg/ha)			Crop N (kg N/ha) per unit GAI		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	2.57		2.57	2.16		2.16	153		153	65.7		65.7
Excalibur	240	4.25	4.41	4.33	3.07	2.85	2.96	303	248	276	56.6	50.2	53.4
Excalibur	Mean	3.41	3.49	3.45	2.62	2.51	2.56	228	201	214	61.2	58.0	59.6
PR45D03	0	2.41		2.41	2.77		2.77	160		160	71.3		71.3
PR45D03	240	4.62	4.19	4.40	3.59	2.90	3.25	285	205	245	54.0	45.5	49.7
PR45D03	Mean	3.52	3.30	3.41	3.18	2.84	3.01	223	183	203	62.6	58.4	60.5
Exc+D03	0	2.49		2.49	2.47		2.47	156		156	68.5		68.5
Exc+D03	240	4.44	4.30	4.37	3.33	2.88	3.10	294	227	261	55.3	47.9	51.6
Exc+D03	Mean	3.46	3.40	3.43	2.90	2.67	2.78	225	192	208	61.9	58.2	60.0
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		20	0.1634	0.788	20	0.215	0.050	20	18.06	0.528	20	3.43	0.786
N management		20	0.1634	0.683	20	0.215	0.306	20	18.06	0.076	20	3.43	0.291
Nrate		20	0.1634	<0.001	20	0.215	0.008	20	18.06	<0.001	20	3.43	<0.001
Var x Man		20	0.2311	0.364	20	0.304	0.591	20	25.55	0.728	20	4.86	0.881
Var x Nrate		20	0.2311	0.474	20	0.304	0.471	20	25.55	0.304	20	4.86	0.188
Man x Nrate		20	0.2311	0.683	20	0.304	0.306	20	25.55	0.076	20	4.86	0.291
Var x Man x Nrate		20	0.3269	0.364	20	0.430	0.591	20	36.13	0.728	20	6.87	0.881

Light interception at mid-flowering

At Terrington, light reflection by the flowers was significantly reduced by Folicur treatment and was higher in PR45D03 than Excalibur (Table 73). At ground level, light interception was again slightly reduced by Folicur treatment and higher for PR45D03 than for Excalibur (P<0.1) (Table 74). Light interception was generally low across all treatments, as the crop was relatively small and thin due to the dry spring.

At Thornholme, light reflection by the flowers was significantly reduced by Folicur treatment and by Canopy Management, and was higher in PR45D03 than Excalibur (Table 75). The differences caused by Folicur and Canopy Management were replicated in measurements of light interception by flowers, but for varieties the difference was reversed, with Excalibur intercepting a greater proportion of light (Table 76). The higher N rate significantly increased light interception at the base of the canopy and was the only factor to significantly increase interception at ground level, probably because interception was over 95% in almost all treatments (Table 77).

At Rosemaund, as at both other sites, light reflection by the flowers was significantly reduced by Folicur treatment and was higher in PR45D03 than Excalibur (Table 78). Surprisingly, there was a slight but significant reduction in reflection in the higher N treatment. The light reflection differences caused by Folicur and variety were replicated in measurements of light interception by the flower and pod layer with Folicur reducing the amount of light intercepted by the flower layer. But the effect of N rate was reversed, with the higher N rate giving increased light interception (Table 79). At ground level more than 95% of light was intercepted by all treatments, but there were still significant differences between Folicur treatments and N rates, as at the base of the canopy (Table 80).

Table 73. Terrington. Percentage of light reflected from flowers.

Variety	N rate	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	140	9.1	9.3	9.2	9.0	8.7	8.9	9.0	9.0	9.0
Excalibur	280	9.7	9.1	9.4	9.0	8.4	8.7	9.4	8.8	9.1
Excalibur	Mean	9.4	9.2	9.3	9.0	8.6	8.8	9.2	8.9	9.0
PR45D03	140	10.6	10.4	10.5	9.7	9.6	9.7	10.2	10.0	10.1
PR45D03	280	10.0	10.8	10.4	8.7	10.4	9.5	9.3	10.6	10.0
PR45D03	Mean	10.3	10.6	10.5	9.2	10.0	9.6	9.8	10.3	10.0
Exc+D03	140	9.9	9.9	9.9	9.4	9.2	9.3	9.6	9.5	9.6
Exc+D03	280	9.9	10.0	9.9	8.9	9.4	9.1	9.4	9.7	9.5
Exc+D03	Mean	9.9	9.9	9.9	9.1	9.3	9.2	9.5	9.6	9.5

Treatment	df	SED	F pr.
Folicur	45	0.311	0.031
Variety	45	0.311	0.003
N management	45	0.311	0.724
Nrate	45	0.311	0.918
Fol x Var	45	0.440	0.546
Fol x Man	45	0.440	0.839
Var x Man	45	0.440	0.160
Fol x Nrate	45	0.440	0.754
Var x Nrate	45	0.440	0.794
Man x Nrate	45	0.440	0.490
Fol x Var x Man	45	0.623	0.583
Fol x Var x Nrate	45	0.623	0.790
Fol x Man x Nrate	45	0.623	0.588
Var x Man x Nrate	45	0.623	0.112
Fol x Var x Man x Nrate	45	0.881	0.873

Table 74. Terrington. Percentage of light intercepted at ground level by the whole canopy

Variety	N rate	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	140	43.9	47.1	45.5	34.4	33.6	34.0	39.1	40.3	39.7
Excalibur	280	48.3	36.5	42.4	43.2	46.0	44.6	45.8	41.3	43.5
Excalibur	Mean	46.1	41.8	43.9	38.8	39.8	39.3	42.4	40.8	41.6
PR45D03	140	45.3	44.9	45.1	42.4	43.3	42.8	43.8	44.1	44.0
PR45D03	280	46.8	50.4	48.6	37.2	51.9	44.6	42.0	51.2	46.6
PR45D03	Mean	46.0	47.7	46.8	39.8	47.6	43.7	42.9	47.6	45.3
Exc+D03	140	44.6	46.0	45.3	38.4	38.4	38.4	41.5	42.2	41.8
Exc+D03	280	47.5	43.5	45.5	40.2	49.0	44.6	43.9	46.2	45.1
Exc+D03	Mean	46.1	44.7	45.4	39.3	43.7	41.5	42.7	44.2	43.5

Treatment	df	SED	F pr.
Folicur	45	2.03	0.062
Variety	45	2.03	0.078
N management	45	2.03	0.456
Nrate	45	2.03	0.120
Fol x Var	45	2.87	0.712
Fol x Man	45	2.87	0.168
Var x Man	45	2.87	0.124
Fol x Nrate	45	2.87	0.147
Var x Nrate	45	2.87	0.777
Man x Nrate	45	2.87	0.692
Fol x Var x Man	45	4.06	0.911
Fol x Var x Nrate	45	4.06	0.063
Fol x Man x Nrate	45	4.06	0.086
Var x Man x Nrate	45	4.06	0.079
Fol x Var x Man x Nrate	45	5.74	0.598

Table 75. Thornholme. Percentage of light reflected from the flowers.

Variety	N rate	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	120	15.0	13.3	14.2	13.9	14.1	14.0	14.5	13.7	14.1
Excalibur	240	14.4	13.2	13.8	14.3	12.5	13.4	14.4	12.8	13.6
Excalibur	Mean	14.7	13.3	14.0	14.1	13.3	13.7	14.4	13.3	13.8
PR45D03	120	17.2	17.5	17.3	16.0	17.1	16.6	16.6	17.3	17.0
PR45D03	240	16.9	17.0	17.0	16.6	15.2	15.9	16.7	16.1	16.4
PR45D03	Mean	17.1	17.3	17.2	16.3	16.1	16.2	16.7	16.7	16.7
Exc+D03	120	16.1	15.4	15.8	15.0	15.6	15.3	15.5	15.5	15.5
Exc+D03	240	15.7	15.1	15.4	15.4	13.8	14.6	15.6	14.5	15.0
Exc+D03	Mean	15.9	15.3	15.6	15.2	14.7	15.0	15.5	15.0	15.3

Treatment	df	SED	F pr.
Folicur	45	0.265	0.024
Variety	45	0.265	<0.001
N management	45	0.265	0.038
Nrate	45	0.265	0.055
Fol x Var	45	0.374	0.234
Fol x Man	45	0.374	0.793
Var x Man	45	0.374	0.030
Fol x Nrate	45	0.374	0.615
Var x Nrate	45	0.374	0.947
Man x Nrate	45	0.374	0.050
Fol x Var x Man	45	0.529	0.377
Fol x Var x Nrate	45	0.529	0.938
Fol x Man x Nrate	45	0.529	0.025
Var x Man x Nrate	45	0.529	0.606
Fol x Var x Man x Nrate	45	0.749	0.983

Table 76. Thornholme. Percentage of light intercepted by the flowers and pods.

Variety	N rate	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	120	67.7	59.5	63.6	64.3	66.0	65.2	66.0	62.7	64.4
Excalibur	240	71.4	68.2	69.8	71.8	63.6	67.7	71.6	65.9	68.8
Excalibur	Mean	69.6	63.8	66.7	68.1	64.8	66.4	68.8	64.3	66.6
PR45D03	120	64.7	64.1	64.4	58.6	57.8	58.2	61.7	60.9	61.3
PR45D03	240	68.1	63.1	65.6	65.2	62.1	63.6	66.6	62.6	64.6
PR45D03	Mean	66.4	63.6	65.0	61.9	59.9	60.9	64.1	61.8	63.0
Exc+D03	120	66.2	61.8	64.0	61.5	61.9	61.7	63.8	61.8	62.8
Exc+D03	240	69.8	65.6	67.7	68.5	62.8	65.7	69.1	64.2	66.7
Exc+D03	Mean	68.0	63.7	65.9	65.0	62.4	63.7	66.5	63.0	64.8

Treatment	df	SED	F pr.
Folicur	45	1.227	0.081
Variety	45	1.227	0.005
N management	45	1.227	0.008
Nrate	45	1.227	0.003
Fol x Var	45	1.735	0.125
Fol x Man	45	1.735	0.504
Var x Man	45	1.735	0.398
Fol x Nrate	45	1.735	0.903
Var x Nrate	45	1.735	0.666
Man x Nrate	45	1.735	0.248
Fol x Var x Man	45	2.453	0.739
Fol x Var x Nrate	45	2.453	0.115
Fol x Man x Nrate	45	2.453	0.202
Var x Man x Nrate	45	2.453	0.844
Fol x Var x Man x Nrate	45	3.469	0.088

Table 77. Thornholme. Percentage of light intercepted at ground level by the whole canopy.

Variety	N rate	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	120	97.1	96.3	96.7	97.2	98.0	97.6	97.2	97.2	97.2
Excalibur	240	98.8	97.1	97.9	99.0	97.7	98.4	98.9	97.4	98.2
Excalibur	Mean	98.0	96.7	97.3	98.1	97.9	98.0	98.0	97.3	97.7
PR45D03	120	96.3	97.1	96.7	94.5	96.5	95.5	95.4	96.8	96.1
PR45D03	240	99.1	97.4	98.3	98.8	98.5	98.6	99.0	98.0	98.5
PR45D03	Mean	97.7	97.2	97.5	96.6	97.5	97.1	97.2	97.4	97.3
Exc+D03	120	96.7	96.7	96.7	95.9	97.3	96.6	96.3	97.0	96.6
Exc+D03	240	99.0	97.2	98.1	98.9	98.1	98.5	98.9	97.7	98.3
Exc+D03	Mean	97.8	97.0	97.4	97.4	97.7	97.5	97.6	97.3	97.5

Treatment	df	SED	F pr.
Folicur	45	0.519	0.788
Variety	45	0.519	0.452
N management	45	0.519	0.575
Nrate	45	0.519	0.002
Fol x Var	45	0.733	0.310
Fol x Man	45	0.733	0.259
Var x Man	45	0.733	0.361
Fol x Nrate	45	0.733	0.618
Var x Nrate	45	0.733	0.188
Man x Nrate	45	0.733	0.070
Fol x Var x Man	45	1.037	0.877
Fol x Var x Nrate	45	1.037	0.325
Fol x Man x Nrate	45	1.037	0.809
Var x Man x Nrate	45	1.037	0.661
Fol x Var x Man x Nrate	45	1.467	0.710

Table 78. Rosemaund. Percentage of light reflected from the flowers.

Variety	N rate	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	120	12.4	12.0	12.2	11.7	11.1	11.4	12.1	11.6	11.8
Excalibur	240	11.7	12.7	12.2	11.2	11.7	11.5	11.5	12.2	11.8
Excalibur	Mean	12.1	12.4	12.2	11.5	11.4	11.4	11.8	11.9	11.8
PR45D03	120	14.1	14.2	14.1	13.8	13.4	13.6	13.9	13.8	13.9
PR45D03	240	13.2	12.8	13.0	12.9	12.8	12.8	13.0	12.8	12.9
PR45D03	Mean	13.6	13.5	13.6	13.3	13.1	13.2	13.5	13.3	13.4
Exc+D03	120	13.3	13.1	13.2	12.7	12.2	12.5	13.0	12.7	12.8
Exc+D03	240	12.4	12.7	12.6	12.1	12.3	12.2	12.2	12.5	12.4
Exc+D03	Mean	12.9	12.9	12.9	12.4	12.2	12.3	12.6	12.6	12.6

Treatment	df	SED	F pr.
Folicur	43	0.195	0.006
Variety	43	0.195	<0.001
N management	43	0.195	0.831
Nrate	43	0.195	0.020
Fol x Var	43	0.275	0.276
Fol x Man	43	0.275	0.590
Var x Man	43	0.275	0.432
Fol x Nrate	43	0.275	0.485
Var x Nrate	43	0.275	0.019
Man x Nrate	43	0.275	0.156
Fol x Var x Man	43	0.389	0.698
Fol x Var x Nrate	43	0.389	0.710
Fol x Man x Nrate	43	0.389	0.745
Var x Man x Nrate	43	0.389	0.100
Fol x Var x Man x Nrate	43	0.551	0.387

Table 79. Rosemaund. Percentage of light intercepted by the pods and flowers.

Variety	N rate	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	120	71.0	65.5	68.3	68.7	66.4	67.5	69.9	65.9	67.9
Excalibur	240	71.7	71.1	71.4	73.1	67.1	70.1	72.4	69.1	70.8
Excalibur	Mean	71.3	68.3	69.8	70.9	66.8	68.8	71.1	67.5	69.3
PR45D03	120	71.7	71.8	71.7	71.0	69.0	70.0	71.3	70.4	70.8
PR45D03	240	75.6	70.5	73.0	75.3	72.4	73.9	75.5	71.4	73.5
PR45D03	Mean	73.6	71.1	72.4	73.1	70.7	71.9	73.4	70.9	72.1
Exc+D03	120	71.3	68.6	70.0	69.8	67.7	68.8	70.6	73.9	69.4
Exc+D03	240	73.7	70.8	72.2	74.2	69.8	72.0	73.9	70.3	72.1
Exc+D03	Mean	72.5	69.7	71.1	72.0	68.7	70.4	72.3	69.2	70.7

Treatment	df	SED	F pr.
Folicur	43	1.261	0.566
Variety	43	1.261	0.031
N management	43	1.261	0.020
Nrate	43	1.261	0.035
Fol x Var	43	1.784	0.827
Fol x Man	43	1.784	0.838
Var x Man	43	1.784	0.662
Fol x Nrate	43	1.784	0.695
Var x Nrate	43	1.784	0.914
Man x Nrate	43	1.784	0.635
Fol x Var x Man	43	2.523	0.803
Fol x Var x Nrate	43	2.523	0.536
Fol x Man x Nrate	43	2.523	0.686
Var x Man x Nrate	43	2.523	0.463
Fol x Var x Man x Nrate	43	3.567	0.209

Table 80. Rosemaund. Percentage of light intercepted at ground level by the whole canopy.

Variety	N rate	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	120	98.6	98.4	98.5	97.3	97.9	97.6	98.0	98.2	98.1
Excalibur	240	98.8	99.2	99.0	98.5	98.9	98.7	98.6	99.0	98.8
Excalibur	Mean	98.7	98.8	98.7	97.9	98.4	98.2	98.3	98.6	98.4
PR45D03	120	98.7	98.3	98.5	98.1	97.7	97.9	98.4	98.0	98.2
PR45D03	240	98.8	98.7	98.8	98.5	99.3	98.9	98.7	99.0	98.8
PR45D03	Mean	98.8	98.5	98.6	98.3	98.5	98.4	98.6	98.5	98.5
Exc+D03	120	98.6	98.3	98.5	97.7	97.8	97.8	98.2	98.1	98.1
Exc+D03	240	98.8	98.9	98.9	98.5	99.1	98.8	98.7	99.0	98.8
Exc+D03	Mean	98.7	98.6	98.7	98.1	98.4	98.3	98.4	98.5	98.5

Treatment	df	SED	F pr.
Folicur	43	0.1798	0.029
Variety	43	0.1798	0.711
N management	43	0.1798	0.542
Nrate	43	0.1798	<0.001
Fol x Var	43	0.2543	0.326
Fol x Man	43	0.2543	0.273
Var x Man	43	0.2543	0.303
Fol x Nrate	43	0.2543	0.079
Var x Nrate	43	0.2543	0.710
Man x Nrate	43	0.2543	0.214
Fol x Var x Man	43	0.3596	0.974
Fol x Var x Nrate	43	0.3596	0.846
Fol x Man x Nrate	43	0.3596	0.889
Var x Man x Nrate	43	0.3596	0.408
Fol x Var x Man x Nrate	43	0.5085	0.273

Crop height

At all sites, there was a large and significant difference in height between Excalibur and the semi-dwarf PR45D03, but no effect of Folicur or N rate. Canopy Management significantly affected height at only one of the three sites.

At Terrington, Excalibur was 31 cm taller than PR45D03 (Table 81). Height was not significantly affected by N rate, Canopy Management or Folicur treatment.

At Thornholme, Excalibur was 39 cm taller than PR45D03 and Canopy Management reduced height by an average of 3 cm across both varieties and N rates (Table 82). Height was not significantly affected by N rate or Folicur treatment.

At Rosemaund, Excalibur was 45 cm taller than PR45D03 (Table 83). Height was not significantly affected by N rate, Canopy Management or Folicur treatment.

Table 81. Terrington. Height (cm) to the top of terminal raceme.

Variety	N rate kg/ha	No Folicur Conv	No Folicur CM	No Folicur Mean	Folicur (1.0 l/ha) Conv	Folicur (1.0 l/ha) CM	Folicur (1.0 l/ha) Mean	Conv Mean	CM Mean	Grand Mean
Excalibur	140	115	118	117	117	116	116	116	117	117
Excalibur	280	117	116	116	116	118	117	117	117	117
Excalibur	Mean	116	117	117	117	117	117	117	117	117
PR45D03	140	87	93	90	86	85	86	86	89	88
PR45D03	280	85	88	86	80	85	82	82	86	84
PR45D03	Mean	86	90	88	83	85	84	84	88	86
Exc+D03	140	101	106	103	102	101	101	101	103	102
Exc+D03	280	101	102	101	98	102	100	100	102	101
Exc+D03	Mean	101	104	102	100	101	100	100	102	101

Treatment	df	SED	F pr.
Folicur	45	1.577	0.242
Variety	45	1.577	<0.001
N management	45	1.577	0.212
Nrate	45	1.577	0.325
Fol x Var	45	2.230	0.186
Fol x Man	45	2.230	0.620
Var x Man	45	2.230	0.355
Fol x Nrate	45	2.230	0.790
Var x Nrate	45	2.230	0.245
Man x Nrate	45	2.230	0.908
Fol x Var x Man	45	3.154	0.745
Fol x Var x Nrate	45	3.154	0.877
Fol x Man x Nrate	45	3.154	0.196
Var x Man x Nrate	45	3.154	0.816
Fol x Var x Man x Nrate	45	4.460	0.935

Table 82. Thornholme. Height (cm) to the top of terminal raceme.

Variety	N rate	No Folicur			Folicur (1.0 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	120	157	151	154	153	156	154	155	153	154
Excalibur	240	155	152	154	157	150	153	156	151	154
Excalibur	Mean	156	151	154	155	153	154	155	152	154
PR45D03	120	119	116	117	116	111	114	118	113	116
PR45D03	240	116	115	116	114	111	112	115	113	114
PR45D03	Mean	117	116	116	115	111	113	116	113	115
Exc+D03	120	138	133	136	135	134	134	136	133	135
Exc+D03	240	135	134	135	135	130	133	135	132	134
Exc+D03	Mean	137	133	135	135	132	134	136	133	134

Treatment	df	SED	F pr.
Folicur	45	1.362	0.256
Variety	45	1.362	<0.001
N management	45	1.362	0.026
Nrate	45	1.362	0.446
Fol x Var	45	1.926	0.212
Fol x Man	45	1.926	0.961
Var x Man	45	1.926	0.930
Fol x Nrate	45	1.926	0.973
Var x Nrate	45	1.926	0.696
Man x Nrate	45	1.926	0.858
Fol x Var x Man	45	2.724	0.354
Fol x Var x Nrate	45	2.724	0.864
Fol x Man x Nrate	45	2.724	0.212
Var x Man x Nrate	45	2.724	0.306
Fol x Var x Man x Nrate	45	3.853	0.306

Table 83. Rosemaund. Height (cm) to the top of terminal raceme.

Variety	N rate	No Folicur			Folicur (1.0 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	120	165	162	163	162	163	162	164	162	163
Excalibur	240	165	165	165	167	161	164	166	163	165
Excalibur	Mean	165	163	164	165	162	163	165	163	164
PR45D03	120	120	119	119	119	117	118	119	118	119
PR45D03	240	120	118	119	119	119	119	120	118	119
PR45D03	Mean	120	118	119	119	118	118	119	118	119
Exc+D03	120	142	140	141	141	140	140	141	140	141
Exc+D03	240	143	142	142	143	140	142	143	141	142
Exc+D03	Mean	142	141	142	142	140	141	142	140	141

Treatment	df	SED	F pr.
Folicur	45	0.962	0.418
Variety	45	0.962	<0.001
N management	45	0.962	0.062
Nrate	45	0.962	0.210
Fol x Var	45	1.361	0.842
Fol x Man	45	1.361	0.809
Var x Man	45	1.361	0.610
Fol x Nrate	45	1.361	0.671
Var x Nrate	45	1.361	0.462
Man x Nrate	45	1.361	0.751
Fol x Var x Man	45	1.924	0.834
Fol x Var x Nrate	45	1.924	0.703
Fol x Man x Nrate	45	1.924	0.382
Var x Man x Nrate	45	1.924	0.573
Fol x Var x Man x Nrate	45	2.722	0.120

Lodging

At Terrington and Thornholme, there was no lodging. At Rosemaund there was a very small amount of leaning (Table 84). Although this was probably insufficient to affect yield, it was significantly reduced by Folicur treatment and slightly lower for PR45D03 than Excalibur ($P<0.1$). There was a significant interaction between Folicur and variety, with Folicur reducing lodging by more for Excalibur than PR45D03. These lodging effects do not correspond to the height measurements, which showed no effect of Folicur at Rosemaund (Table 83), which therefore indicates that changes to other canopy characteristics may have caused the differences in lodging risk.

Table 84. Rosemaund. Percentage of plot area leaning at 10-45 degrees from vertical, at harvest.

Variety	N rate	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	0	2.50		2.50	0.00		0.00	1.25		1.25
Excalibur	70	2.50	0.00	1.25	0.00	0.00	0.00	1.25	0.00	0.63
Excalibur	140	2.50	0.00	1.25	1.25	0.00	0.63	1.88	0.00	0.94
Excalibur	210	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Excalibur	280	2.50	2.50	2.50	0.00	0.00	0.00	1.25	1.25	1.25
Excalibur	350	1.25	1.25	1.25	0.00	1.25	0.63	0.63	1.25	0.94
Excalibur	Mean	1.88	1.04	1.46	0.21	0.21	0.21	1.04	0.63	0.83
PR45D03	0	1.25		1.25	1.25		1.25	1.25		1.25
PR45D03	70	1.25	0.00	0.63	0.00	0.00	0.00	0.63	0.00	0.31
PR45D03	140	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR45D03	210	0.00	0.00	0.00	0.00	1.25	0.63	0.00	0.63	0.31
PR45D03	280	0.00	1.25	0.63	0.00	0.00	0.00	0.00	0.63	0.31
PR45D03	350	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR45D03	Mean	0.42	0.42	0.42	0.21	0.42	0.31	0.31	0.42	0.36
Exc+D03	0	1.88		1.88	0.63		0.63	1.25		1.25
Exc+D03	70	1.88	0.00	0.94	0.00	0.00	0.00	0.94	0.00	0.47
Exc+D03	140	1.25	0.00	0.63	0.63	0.00	0.31	0.94	0.00	0.47
Exc+D03	210	0.00	0.00	0.00	0.00	0.63	0.31	0.00	0.31	0.16
Exc+D03	280	1.25	1.88	1.56	0.00	0.00	0.00	0.63	0.94	0.78
Exc+D03	350	0.63	0.63	0.63	0.00	0.63	0.31	0.31	0.63	0.47
Exc+D03	Mean	1.15	0.73	0.94	0.21	0.31	0.26	0.68	0.52	0.60

Treatment	df	SED	F pr.
Folicur	141	0.258	0.010
Variety	141	0.258	0.071
N management	141	0.258	0.545
N rate	141	0.446	0.223
Fol x Var	141	0.365	0.028
Fol x Man	141	0.365	0.314
Var x Man	141	0.365	0.314
Fol x Nrate	141	0.631	0.304
Var x Nrate	141	0.631	0.580
Man x Nrate	141	0.631	0.447
Fol x Var x Man	141	0.515	0.545
Fol x Var x Nrate	141	0.893	0.825
Fol x Man x Nrate	141	0.893	0.825
Var x Man x Nrate	141	0.893	0.825
Fol x Var x Man x Nrate	141	1.263	0.973

Biomass at harvest

At Terrington, increasing N rate from 0 to 280 kg N/ha significantly increased the biomass of all plant parts. Excalibur had a significantly higher stem biomass than PR45D03. The total biomass of Excalibur was about 0.6 t/ha greater than PR45D03, but this difference was not statistically significant. There were no significant effects of Canopy Management (Table 85).

At Thornholme, increased N rate significantly ($P < 0.05$) increased the biomass of the seeds, stems and whole crop, but not of pod walls ($P = 0.125$; Table 86). There were no effects of variety or Canopy Management on total biomass or the fractions of plant biomass.

At Rosemaund, as at Terrington, increased N rate significantly increased the biomass of all plant parts, Excalibur had a higher stem biomass than PR45D03. The total biomass of Excalibur was about 1 t/ha greater than PR45D03, but this difference was not statistically significant. There were no significant effects of Canopy Management (Table 87).

Table 85. Terrington. Pre-harvest measurement of dry matter (t/ha) for plots without Folicur.

Variety	N rate kg/ha	Total plant dry matter (t/ha) Conv	CM	Mean	Seed dry matter (t/ha) Conv	CM	Mean	Stem dry matter (t/ha) Conv	CM	Mean	Pod wall dry matter (t/ha) Conv	CM	Mean
Excalibur	0	4.55		4.55	1.39		1.39	1.67		1.67	1.49		1.49
Excalibur	280	8.95	8.42	8.69	3.16	3.11	3.14	3.07	2.72	2.90	2.72	2.59	2.65
Excalibur	Mean	6.75	6.49	6.62	2.28	2.25	2.26	2.37	2.20	2.28	2.11	2.04	2.07
PR45D03	0	4.50		4.50	1.64		1.64	1.33		1.33	1.53		1.53
PR45D03	280	7.29	7.73	7.51	2.96	3.16	3.06	2.13	2.24	2.18	2.20	2.33	2.27
PR45D03	Mean	5.89	6.11	6.00	2.30	2.40	2.35	1.73	1.78	1.76	1.87	1.93	1.90
Exc+D03	0	4.53		4.53	1.52		1.52	1.50		1.50	1.51		1.51
Exc+D03	280	8.12	8.07	8.10	3.06	3.13	3.10	2.60	2.48	2.54	2.46	2.46	2.46
Exc+D03	Mean	6.32	6.30	6.31	2.29	2.32	2.31	2.05	1.99	2.02	1.99	1.98	1.98
Treatment		df	SED	F Pr.	df	SED	F Pr.	df	SED	F Pr.	df	SED	F Pr.
Variety		21	0.381	0.121	21	0.1183	0.473	21	0.1504	0.002	21	0.1431	0.236
N management		21	0.381	0.950	21	0.1183	0.764	21	0.1504	0.701	21	0.1431	0.990
Nrate		21	0.381	<0.001	21	0.1183	<0.001	21	0.1504	<0.001	21	0.1431	<0.001
Var x Man		21	0.539	0.531	21	0.1673	0.591	21	0.2127	0.459	21	0.2023	0.655
Var x Nrate		21	0.539	0.155	21	0.1673	0.177	21	0.2127	0.233	21	0.2023	0.152
Man x Nrate		21	0.539	0.950	21	0.1673	0.764	21	0.2127	0.701	21	0.2023	0.990
Var x Man x Nrate		21	0.762	0.531	21	0.2367	0.591	21	0.3008	0.459	21	0.2861	0.655

Table 86. Thornholme. Pre-harvest measurement of dry matter (t/ha) for plots without Folicur.

Variety	N rate	Total plant dry matter (t/ha)			Seed dry matter (t/ha)			Stem dry matter (t/ha)			Pod wall dry matter (t/ha)		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	10.8		10.8	2.90		2.90	4.15		4.15	3.75		3.75
Excalibur	240	14.1	12.4	13.2	4.57	4.32	4.44	5.34	4.39	4.86	4.16	3.66	3.91
Excalibur	Mean	12.4	11.6	12.0	3.73	3.61	3.67	4.74	4.27	4.51	3.95	3.70	3.83
PR45D03	0	10.8		10.8	3.18		3.18	3.76		3.76	3.84		3.84
PR45D03	240	12.8	13.6	13.2	4.27	4.49	4.38	4.36	4.54	4.45	4.21	4.56	4.38
PR45D03	Mean	11.8	12.2	12.0	3.72	3.83	3.78	4.06	4.15	4.11	4.02	4.20	4.11
Exc+D03	0	10.8		10.8	3.04		3.04	3.96		3.96	3.79		3.79
Exc+D03	240	13.5	13.0	13.2	4.42	4.41	4.41	4.85	4.47	4.66	4.19	4.11	4.15
Exc+D03	Mean	12.1	11.9	12.0	3.73	3.72	3.73	4.40	4.21	4.31	3.99	3.95	3.97
Treatment		df	SED	F Pr.	df	SED	F Pr.	df	SED	F Pr.	df	SED	F Pr.
Variety		21	0.483	0.969	21	0.1186	0.394	21	0.253	0.125	21	0.228	0.231
N management		21	0.483	0.631	21	0.1186	0.963	21	0.253	0.456	21	0.228	0.871
Nrate		21	0.483	<.001	21	0.1186	<.001	21	0.253	0.011	21	0.228	0.135
Var x Man		21	0.683	0.222	21	0.1678	0.34	21	0.358	0.282	21	0.322	0.361
Var x Nrate		21	0.683	0.98	21	0.1678	0.17	21	0.358	0.967	21	0.322	0.411
Man x Nrate		21	0.683	0.631	21	0.1678	0.963	21	0.358	0.456	21	0.322	0.871
Var x Man x Nrate		21	0.966	0.222	21	0.2373	0.34	21	0.506	0.282	21	0.456	0.361

Table 87. Rosemaund. Pre-harvest measurement of dry matter (t/ha) for plots without Folicur.

Variety	N rate	Total plant dry matter (t/ha)			Seed dry matter (t/ha)			Stem dry matter (t/ha)			Pod wall dry matter (t/ha)		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	9.57		9.57	3.14		3.14	3.73		3.73	2.71		2.71
Excalibur	240	14.15	12.98	13.56	4.30	4.32	4.31	5.29	4.77	5.03	4.56	3.89	4.22
Excalibur	Mean	11.90	11.23	11.57	3.76	3.68	3.72	4.50	4.26	4.38	3.64	3.29	3.47
PR45D03	0	8.24		8.24	2.99		2.99	2.83		2.83	2.41		2.41
PR45D03	240	12.12	13.73	12.93	4.54	4.46	4.50	3.87	4.61	4.24	3.72	4.66	4.59
PR45D03	Mean	10.15	11.02	10.58	3.77	3.73	3.75	3.33	3.74	3.54	3.05	3.55	3.30
Exc+D03	0	8.90		8.90	3.06		3.06	3.28		3.28	2.56		2.56
Exc+D03	240	13.13	13.35	13.24	4.42	4.39	4.40	4.58	4.69	4.63	4.14	4.27	4.21
Exc+D03	Mean	11.02	11.12	11.07	3.76	3.70	3.73	3.92	4.00	3.96	3.34	3.42	3.38
Treatment		df	SED	F Pr.	df	SED	F Pr.	df	SED	F Pr.	df	SED	F Pr.
Variety		17	0.786	0.227	17	0.1476	0.876	17	0.271	0.006	17	0.431	0.708
N management		17	0.786	0.899	17	0.1476	0.698	17	0.271	0.769	17	0.431	0.857
Nrate		17	0.786	<0.001	17	0.1476	<0.001	17	0.271	<0.001	17	0.431	0.001
Var x Man		17	1.111	0.344	17	0.2088	0.900	17	0.384	0.249	17	0.610	0.341
Var x Nrate		17	1.111	0.663	17	0.2088	0.276	17	0.384	0.850	17	0.610	0.766
Man x Nrate		17	1.111	0.884	17	0.2088	0.863	17	0.384	0.900	17	0.610	0.898
Var x Man x Nrate		17	1.572	0.440	17	0.2953	0.664	17	0.543	0.274	17	0.862	0.390

Crop N content

At Terrington, increasing N rate from 0 to 280 kg N/ha increased the total N uptake from 56 to 134 kg N/ha (Table 89). This effect was caused by a combination of greater biomass (Table 85) and greater tissue N concentration (Table 88) in both the seed and other plant parts. There were no significant differences between Excalibur and PR45D03 in total N uptake, although Excalibur did have a higher seed N concentration than PR45D03. There were no significant effects of Canopy Management.

At Thornholme, increasing N rate from 0 to 240 kg N/ha increased the total N uptake from 132 to 221 kg N/ha (Table 91). This effect was caused by a combination of greater biomass (Table 86) and greater tissue N concentration (Table 90) in both the seed and stems. Although Excalibur gave 0.22 % higher (P = 0.003; Table 90) seed N concentration when averaged over N rates, there was no significant difference in the seed N yield or total N uptake (Table 91). There was no effect of N management on N uptake, although there was some evidence that the Canopy Management treatment gave greater seed N concentrations (P = 0.082; Table 90).

At Rosemaund, increasing N rate from 0 to 240 kg N/ha increased the total N uptake from 113 to 242 kg N/ha (Table 93). This effect was caused by a combination of greater biomass (Table 87) and greater tissue N concentration (Table 92) in both the seed and other plant parts. There were no significant effects of Canopy Management or variety on total N uptake. There was an interaction between variety and N rate for seed N concentration, such that N concentration responded more to N application in PR45D03 than Excalibur.

Table 88. Terrington. Pre-harvest measurement of nitrogen concentration for plots without Folicur.

Variety	N rate	Seed N %			Stem and pod wall N %		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	2.432		2.432	0.684		0.684
Excalibur	280	2.889	3.055	2.972	0.828	0.908	0.868
Excalibur	Mean	2.660	2.744	2.702	0.756	0.796	0.776
PR45D03	0	2.240		2.240	0.678		0.678
PR45D03	280	2.631	2.830	2.731	0.881	0.957	0.919
PR45D03	Mean	2.436	2.535	2.485	0.780	0.817	0.798
Exc+D03	0	2.336		2.336	0.681		0.681
Exc+D03	280	2.760	2.943	2.851	0.854	0.933	0.894
Exc+D03	Mean	2.548	2.640	2.594	0.768	0.807	0.787
Treatment		df	SED	F pr.	df	SED	F pr.
Variety		21	0.0557	<0.001	21	0.0330	0.498
N management		21	0.0557	0.115	21	0.0330	0.249
Nrate		21	0.0557	<0.001	21	0.0330	<0.001
Var x Man		21	0.0788	0.885	21	0.0466	0.970
Var x Nrate		21	0.0788	0.662	21	0.0466	0.397
Man x Nrate		21	0.0788	0.115	21	0.0466	0.249
Var x Man x Nrate		21	0.1114	0.885	21	0.0659	0.970

Table 89. Terrington. Pre-harvest measurement of N content for plots without Folicur.

Variety	N rate	Seed N yield (kg/ha)			Stem and pod wall N yield (kg/ha)			Total N yield (kg/ha)		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	33.9		33.9	22.5		22.5	56.4		56.4
Excalibur	280	91.7	95.0	93.3	48.7	48.8	48.7	140.4	143.7	142.0
Excalibur	Mean	62.8	64.5	63.6	35.6	35.6	35.6	98.4	100.1	99.2
PR45D03	0	36.8		36.8	19.4		19.4	56.2		56.2
PR45D03	280	78.5	89.5	84.0	38.7	44.1	41.4	117.2	133.6	125.4
PR45D03	Mean	57.6	63.2	60.4	29.1	31.8	30.4	86.7	94.9	90.8
Exc+D03	0	35.4		35.4	21.0		21.0	56.3		56.3
Exc+D03	280	85.1	92.2	88.7	43.7	46.4	45.0	128.8	138.7	133.7
Exc+D03	Mean	60.2	63.8	62.0	32.3	33.7	33.0	92.6	97.5	95.0
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		21	3.95	0.420	21	3.51	0.154	21	6.96	0.239
N management		21	3.95	0.377	21	3.51	0.697	21	6.96	0.485
Nrate		21	3.95	<0.001	21	3.51	<0.001	21	6.96	<0.001
Var x Man		21	5.58	0.627	21	4.96	0.708	21	9.84	0.642
Var x Nrate		21	5.58	0.138	21	4.96	0.550	21	9.84	0.251
Man x Nrate		21	5.58	0.377	21	4.96	0.697	21	9.84	0.485
Var x Man x Nrate		21	7.89	0.627	21	7.01	0.708	21	13.91	0.642

Table 90. Thornholme. Pre-harvest measurement of nitrogen concentration for plots without Folicur.

Variety	N rate kg/ha	Seed N %			Stem and pod wall N %		
		Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	2.42		2.42	0.78		0.78
Excalibur	240	3.07	3.35	3.21	0.99	0.96	0.97
Excalibur	Mean	2.75	2.89	2.82	0.88	0.87	0.87
PR45D03	0	2.35		2.35	0.74		0.74
PR45D03	240	2.77	2.95	2.86	0.91	1.03	0.97
PR45D03	Mean	2.56	2.65	2.60	0.83	0.89	0.86
Exc+D03	0	2.39		2.39	0.76		0.76
Exc+D03	240	2.92	3.15	3.03	0.95	1.00	0.97
Exc+D03	Mean	2.65	2.77	2.71	0.85	0.88	0.87
Treatment		df	SED	F pr.	df	SED	F pr.
Variety		21	0.0636	0.003	21	0.0433	0.691
N management		21	0.0636	0.082	21	0.0433	0.572
Nrate		21	0.0636	<.001	21	0.0433	<.001
Var x Man		21	0.0899	0.704	21	0.0613	0.405
Var x Nrate		21	0.0899	0.046	21	0.0613	0.75
Man x Nrate		21	0.0899	0.082	21	0.0613	0.572
Var x Man x Nrate		21	0.1271	0.704	21	0.0867	0.405

Table 91. Thornholme. Pre-harvest measurement of N content for plots without Folicur.

Variety	N rate	Seed N yield (kg/ha)			Stem and pod wall N yield (kg/ha)			Total N yield (kg/ha)		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	74.6		74.6	63.0		63.0	133.3		133.3
Excalibur	240	118.2	132.4	125.3	96.7	77.5	87.1	237.3	222.7	230.0
Excalibur	Mean	96.4	103.5	100.0	79.9	70.2	75.0	185.3	178.0	181.7
PR45D03	0	70.4		70.4	56.3		56.3	130.9		130.9
PR45D03	240	140.6	145.2	142.9	77.9	94.1	86.0	196.2	226.5	211.3
PR45D03	Mean	105.5	107.8	106.6	67.1	75.2	71.1	163.5	178.7	171.1
Exc+D03	0	72.5		72.5	59.6		59.6	132.1		132.1
Exc+D03	240	129.4	138.8	134.1	87.3	85.8	86.6	216.8	224.6	220.7
Exc+D03	Mean	101.0	105.7	103.3	73.5	72.7	73.1	174.4	178.4	176.4
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		21	4.37	0.142	21	6.06	0.527	21	8.84	0.246
N management		21	4.37	0.293	21	6.06	0.9	21	8.84	0.661
Nrate		21	4.37	<.001	21	6.06	<.001	21	8.84	<.001
Var x Man		21	6.18	0.591	21	8.57	0.159	21	12.51	0.218
Var x Nrate		21	6.18	0.021	21	8.57	0.65	21	12.51	0.369
Man x Nrate		21	6.18	0.293	21	8.57	0.9	21	12.51	0.661
Var x Man x Nrate		21	8.73	0.591	21	12.12	0.159	21	17.69	0.218

Table 92. Rosemaund. Pre-harvest measurement of nitrogen concentration for plots without Folicur.

Variety	N rate	Seed N %			Stem and pod wall N %		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	2.455		2.455	0.680		0.680
Excalibur	240	3.181	2.962	3.071	1.272	1.046	1.159
Excalibur	Mean	2.818	2.709	2.763	0.976	0.863	0.920
PR45D03	0	2.310		2.310	0.663		0.663
PR45D03	240	3.102	3.130	3.116	1.066	1.058	1.062
PR45D03	Mean	2.706	2.720	2.713	0.865	0.861	0.863
Exc+D03	0	2.38		2.383	0.672		0.672
Exc+D03	240	3.14	3.05	3.094	1.169	1.052	1.111
Exc+D03	Mean	2.762	2.714	2.738	0.921	0.862	0.891
Treatment		df	SED	F pr.	df	SED	F pr.
Variety		21	0.0370	0.190	21	0.0792	0.481
N management		21	0.0370	0.211	21	0.0792	0.466
Nrate		21	0.0370	<0.001	21	0.0792	<0.001
Var x Man		21	0.0523	0.110	21	0.1120	0.497
Var x Nrate		21	0.0523	0.018	21	0.1120	0.618
Man x Nrate		21	0.0523	0.211	21	0.1120	0.466
Var x Man x Nrate		21	0.0740	0.110	21	0.1584	0.497

Table 93. Rosemaund. Pre-harvest measurement of N content for plots without Folicur.

Variety	N rate	Seed N yield (kg/ha)			Stem and pod wall N yield (kg/ha)			Total N yield (kg/ha))		
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Conv	CM	Mean
Excalibur	0	79.1		79.1	42.7		42.7	121.8		121.8
Excalibur	240	134.4	127.6	131.0	130.6	95.7	113.2	265.1	223.4	244.2
Excalibur	Mean	106.8	103.3	105.1	86.7	69.2	78.0	193.4	172.6	183.0
PR45D03	0	69.4		69.4	34.4		34.4	103.7		103.7
PR45D03	240	140.6	142.3	141.5	81.6	114.8	98.2	222.3	257.2	139.7
PR45D03	Mean	105.0	105.9	105.4	58.0	74.6	66.3	163.0	180.5	171.7
Exc+D03	0	74.2		74.2	38.6		38.6	112.8		112.8
Exc+D03	240	137.5	135.0	136.3	106.1	105.3	105.7	243.7	240.3	242.0
Exc+D03	Mean	105.9	104.6	105.2	72.3	71.9	72.1	178.2	176.5	177.4
Treatment		df	SED	F pr.	df	SED	F pr.	df	SED	F pr.
Variety		17	4.24	0.931	17	13.90	0.413	17	16.16	0.494
N management		17	4.24	0.767	17	13.90	0.976	17	16.16	0.918
Nrate		17	4.24	<0.001	17	13.90	<0.001	17	16.16	<0.001
Var x Man		17	5.99	0.622	17	19.66	0.238	17	22.86	0.252
Var x Nrate		17	5.99	0.029	17	19.66	0.816	17	22.86	0.679
Man x Nrate		17	5.99	0.767	17	19.66	0.976	17	22.86	0.918
Var x Man x Nrate		17	8.48	0.622	17	27.81	0.238	17	32.33	0.252

Seed size and seed number

At Terrington, increasing N rate significantly reduced seed weight (Table 94), showing that the yield response to N must have been caused entirely by increased seed number (Table 95). Canopy Management also caused a small but significant increase in seed weight, relative to conventional N timings. There were no significant effects of Folicur or variety on seed size. Besides the effect of N rate on seed number, there were slight increases due to Folicur and PR45D03 ($P<0.1$), showing that the yield effect of Folicur was also through increased seed number.

At Thornholme, PR45D03 gave significantly ($P<0.001$) smaller seed size but a significantly greater number ($P = 0.01$) of seeds than Excalibur (Tables 96 and 97); TSW was 5.37 and 5.59 g for PR45D03 and Excalibur, respectively. There was a significant interaction ($P = 0.003$) in TSW between variety and N rate whereby in Excalibur TSW was reduced when N was applied but in PR45D03, TSW did not differ up to the 180 kg N/ha N rate and was increased at 300 kgN/ha

(Table 96). This was not seen in the seed number data, but the highly significant increases in seed number with N rate showed that most of the increase in yield due to increasing N rate can be explained by seed numbers rather than seed size (Table 97). There was also a significant (P = 0.004) Folicur x N rate interaction on TSW; where no Folicur was applied TSW was reduced when N was applied whereas when Folicur was applied this was not the case (Table 96).

At Rosemaund, none of the factors tested had a significant effect on seed weight (Table 98). Seed number was significantly increased by increased N rate and by Folicur application (Table 99), showing that the yield results are entirely due to differences in seed number, rather than seed weight.

Table 94. Terrington. Thousand seed weight (g) at 91% DM.

Variety	N rate kg/ha	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
		Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	0	5.17		5.17	5.02		5.02	5.09		5.09
Excalibur	70	5.14	5.03	5.08	4.90	5.10	5.00	5.02	5.06	5.04
Excalibur	210	4.92	4.89	4.91	4.99	5.07	5.03	4.96	4.98	4.97
Excalibur	350	4.94	4.95	4.94	4.49	5.12	4.81	4.72	5.03	4.88
Excalibur	Mean	5.04	5.01	5.02	4.85	5.08	4.96	4.95	5.04	4.99
PR45D03	0	4.99		4.99	5.58		5.58	5.29		5.29
PR45D03	70	4.94	4.75	4.84	4.62	5.17	4.89	4.78	4.96	4.87
PR45D03	210	4.84	4.78	4.81	4.85	4.91	4.88	4.85	4.85	4.85
PR45D03	350	4.80	5.01	4.91	4.83	5.12	4.97	4.82	5.07	4.94
PR45D03	Mean	4.89	4.88	4.89	4.97	5.20	5.08	4.93	5.04	4.99
Exc+D03	0	5.08		5.08	5.30		5.30	5.19		5.19
Exc+D03	70	5.04	4.89	4.96	4.76	5.14	4.95	4.90	5.01	4.95
Exc+D03	210	4.88	4.84	4.86	4.92	4.99	4.96	4.90	4.91	4.91
Exc+D03	350	4.87	4.98	4.93	4.66	5.12	4.89	4.77	5.05	4.91
Exc+D03	Mean	4.97	4.95	4.96	4.91	5.14	5.02	4.94	5.04	4.99

Treatment	df	SED	F pr.
Folicur	93	0.0467	0.158
Variety	93	0.0467	0.875
N management	93	0.0467	0.031
Nrate	93	0.0660	<0.001
Fol x Var	93	0.0660	0.008
Fol x Man	93	0.0660	0.009
Var x Man	93	0.0660	0.898
Fol x Nrate	93	0.0933	0.186
Var x Nrate	93	0.0933	0.023
Man x Nrate	93	0.0933	0.127
Fol x Var x Man	93	0.0933	0.883
Fol x Var x Nrate	93	0.1320	0.024
Fol x Man x Nrate	93	0.1320	0.186
Var x Man x Nrate	93	0.1320	0.889
Fol x Var x Man x Nrate	93	0.1866	0.333

Table 95. Terrington. Seeds per m^2 (calculated from thousand seed weight and combine seed yield).

Variety	N rate	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	0	29519		29519	33246		33246	31383		31383
Excalibur	60	47307	50596	48951	49204	47816	48510	48255	49206	48731
Excalibur	180	68445	69000	68723	72644	72640	72642	70545	70820	70682
Excalibur	300	74504	71808	73156	89184	74332	81758	81844	73070	77457
Excalibur	Mean	54944	55231	55087	61070	57008	59039	58007	56120	57063
PR45D03	0	36228		36228	33147		33147	34687		34687
PR45D03	60	49762	57745	53753	58403	52699	55551	54083	55222	54652
PR45D03	180	69513	72987	71250	78801	81817	80309	74157	77402	75780
PR45D03	300	75910	73637	74774	77913	71612	74763	76911	72625	74768
PR45D03	Mean	57853	60149	59001	62066	59819	60942	59960	59984	59972
Exc+D03	0	32874		32874	33196		33196	33035		33035
Exc+D03	60	48534	54170	51352	53804	50257	52031	51169	52214	51691
Exc+D03	180	68979	70994	69986	75723	77229	76476	72351	74111	73231
Exc+D03	300	75207	72723	73965	83548	72972	78260	79378	72847	76113
Exc+D03	Mean	56399	57690	57044	61568	58414	59991	58983	58052	58518

Treatment	df	SED	F pr.
Folicur	93	1713	0.089
Variety	93	1713	0.093
N management	93	1713	0.588
Nrate	93	2423	<0.001
Fol x Var	93	2423	0.559
Fol x Man	93	2423	0.198
Var x Man	93	2423	0.578
Fol x Nrate	93	3426	0.525
Var x Nrate	93	3426	0.283
Man x Nrate	93	3426	0.303
Fol x Var x Man	93	3426	0.977
Fol x Var x Nrate	93	4845	0.413
Fol x Man x Nrate	93	4845	0.680
Var x Man x Nrate	93	4845	0.959
Fol x Var x Man x Nrate	93	6852	0.853

Table 96. Thornholme. Thousand seed weight (g) at 91% DM.

Variety	N rate	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	0	5.80		5.80	5.69		5.69	5.74		5.74
Excalibur	60	5.47	5.45	5.46	5.56	5.68	5.62	5.51	5.56	5.54
Excalibur	180	5.55	5.48	5.51	5.60	5.49	5.55	5.58	5.49	5.53
Excalibur	300	5.29	5.69	5.49	5.60	5.69	5.65	5.45	5.69	5.57
Excalibur	Mean	5.52	5.60	5.56	5.61	5.64	5.62	5.57	5.62	5.59
PR45D03	0	5.45		5.45	5.23		5.23	5.34		5.34
PR45D03	60	5.28	5.25	5.26	5.38	5.36	5.37	5.33	5.31	5.32
PR45D03	180	5.27	5.30	5.29	5.31	5.41	5.36	5.29	5.36	5.32
PR45D03	300	5.45	5.52	5.49	5.52	5.51	5.52	5.49	5.51	5.50
PR45D03	Mean	5.36	5.38	5.37	5.36	5.38	5.37	5.36	5.38	5.37
Exc+D03	0	5.62		5.62	5.46		5.46	5.54		5.54
Exc+D03	60	5.37	5.35	5.36	5.47	5.52	5.50	5.42	5.44	5.43
Exc+D03	180	5.41	5.39	5.40	5.46	5.45	5.46	5.43	5.42	5.43
Exc+D03	300	5.37	5.60	5.49	5.56	5.60	5.58	5.47	5.60	5.53
Exc+D03	Mean	5.44	5.49	5.47	5.49	5.51	5.50	5.47	5.50	5.48

Treatment	df	SED	F pr.
Folicur	93	0.0309	0.333
Variety	93	0.0309	<.001
N management	93	0.0309	0.277
Nrate	93	0.0437	0.008
Fol x Var	93	0.0437	0.311
Fol x Man	93	0.0437	0.684
Var x Man	93	0.0437	0.587
Fol x Nrate	93	0.0619	0.004
Var x Nrate	93	0.0619	0.003
Man x Nrate	93	0.0619	0.33
Fol x Var x Man	93	0.0619	0.65
Fol x Var x Nrate	93	0.0875	0.753
Fol x Man x Nrate	93	0.0875	0.425
Var x Man x Nrate	93	0.0875	0.202
Fol x Var x Man x Nrate	93	0.1237	0.752

Table 97. Thornholme. Seeds/m^2 (calculated from thousand seed weight and combine seed yield).

Variety	N rate	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	0	53875		53875	64235		64235	59055		59055
Excalibur	60	78860	76068	77464	74036	73063	73549	76448	74565	75507
Excalibur	180	88657	84987	86822	89069	91000	90035	88863	87993	88428
Excalibur	300	96078	88925	92502	95341	91357	93349	95709	90141	92925
Excalibur	Mean	79368	75964	77666	80670	79914	80292	80019	77939	78979
PR45D03	0	63048		63048	68989		68989	66018		66018
PR45D03	60	79518	81222	80370	76709	77291	77000	78114	79256	78685
PR45D03	180	91993	97081	94537	93032	89506	91269	92512	93293	92903
PR45D03	300	93706	91860	92783	90313	93477	91895	92010	92669	92339
PR45D03	Mean	82066	83303	82685	82261	82316	82288	82164	82809	82486
Exc+D03	0	58462		58462	66612		66612	62537		62537
Exc+D03	60	79189	78645	78917	75373	75177	75275	77281	76911	77096
Exc+D03	180	90325	91034	90679	91051	90253	90652	90688	90643	90666
Exc+D03	300	94892	90392	92642	92827	92417	92622	93860	91405	92632
Exc+D03	Mean	80717	79633	80175	81466	81115	81290	81091	80374	80733

Treatment	df	SED	F pr.
Folicur	93	1330.1	0.404
Variety	93	1330.1	0.01
N management	93	1330.1	0.591
Nrate	93	1881	<.001
Fol x Var	93	1881	0.259
Fol x Man	93	1881	0.784
Var x Man	93	1881	0.308
Fol x Nrate	93	2660.2	0.018
Var x Nrate	93	2660.2	0.247
Man x Nrate	93	2660.2	0.901
Fol x Var x Man	93	2660.2	0.474
Fol x Var x Nrate	93	3762	0.801
Fol x Man x Nrate	93	3762	0.896
Var x Man x Nrate	93	3762	0.864
Fol x Var x Man x Nrate	93	5320.3	0.712

Table 98. Rosemaund. Thousand seed weight (g) at 91% DM.

Variety	N rate	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	0	5.29		5.29	5.20		5.20	5.24		5.24
Excalibur	60	5.17	5.10	5.14	5.18	5.21	5.19	5.18	5.15	5.16
Excalibur	180	5.34	5.26	5.30	5.42	5.10	5.26	5.38	5.18	5.28
Excalibur	300	5.44	5.43	5.43	5.51	5.28	5.39	5.47	5.35	5.41
Excalibur	Mean	5.31	5.27	5.29	5.33	5.20	5.26	5.32	5.23	5.28
PR45D03	0	5.16		5.16	5.26		5.26	5.21		5.21
PR45D03	60	5.19	5.32	5.25	5.16	5.30	5.23	5.17	5.31	5.24
PR45D03	180	5.37	5.23	5.30	5.25	5.31	5.28	5.31	5.27	5.29
PR45D03	300	5.21	5.29	5.25	5.26	5.21	5.23	5.24	5.25	5.24
PR45D03	Mean	5.23	5.25	5.24	5.23	5.27	5.25	5.23	5.26	5.25
Exc+D03	0	5.22		5.22	5.23		5.23	5.23		5.23
Exc+D03	60	5.18	5.21	5.20	5.17	5.25	5.21	5.17	5.23	5.20
Exc+D03	180	5.35	5.25	5.30	5.34	5.20	5.27	5.35	5.23	5.29
Exc+D03	300	5.33	5.36	5.34	5.39	5.24	5.31	5.36	5.30	5.33
Exc+D03	Mean	5.27	5.26	5.27	5.28	5.23	5.26	5.28	5.25	5.26

Treatment	df	SED	F pr.
Folicur	93	0.0409	0.827
Variety	93	0.0409	0.481
N management	93	0.0409	0.464
Nrate	93	0.0579	0.132
Fol x Var	93	0.0579	0.678
Fol x Man	93	0.0579	0.673
Var x Man	93	0.0579	0.177
Fol x Nrate	93	0.0818	0.968
Var x Nrate	93	0.0818	0.185
Man x Nrate	93	0.0818	0.467
Fol x Var x Man	93	0.0818	0.517
Fol x Var x Nrate	93	0.1157	0.706
Fol x Man x Nrate	93	0.1157	0.773
Var x Man x Nrate	93	0.1157	0.887
Fol x Var x Man x Nrate	93	0.1637	0.677

Table 99. Rosemaund. seeds/m^2 (calculated from thousand seed weight and combine seed yield).

Variety	N rate	No Folicur			Folicur (0.5 l/ha)			Conv	CM	Grand
	kg/ha	Conv	CM	Mean	Conv	CM	Mean	Mean	Mean	Mean
Excalibur	0	64773		64773	74942		74942	69858		69858
Excalibur	60	87151	89771	88461	97650	97191	97420	92401	93481	92941
Excalibur	180	77632	100118	88875	95637	115349	105493	86635	107733	97184
Excalibur	300	92836	93399	93117	104964	108659	106811	98900	101029	99964
Excalibur	Mean	80598	87015	83807	93298	99035	96167	86948	93025	89987
PR45D03	0	63783		63783	67402		67402	65592		65592
PR45D03	60	80605	78947	79776	85603	92579	89091	83104	85763	84434
PR45D03	180	93423	94183	93803	111108	109109	110109	102265	101646	101956
PR45D03	300	95344	90728	93036	113330	109819	111575	104337	100273	102305
PR45D03	Mean	83289	81910	82599	94361	94727	94544	88825	88319	88572
Exc+D03	0	64278		64278	71172		71172	67725		67725
Exc+D03	60	83878	84359	84119	91626	94885	93256	87752	89622	88687
Exc+D03	180	85527	97150	91339	103373	112229	107801	94450	104690	99570
Exc+D03	300	94090	92063	93077	109147	109239	109193	101619	100651	101135
Exc+D03	Mean	81943	84463	83203	93830	96881	95355	87886	90672	89279

Treatment	df	SED	F pr.
Folicur	88	1851	<0.001
Variety	88	1851	0.447
N management	88	1851	0.136
Nrate	88	2618	<0.001
Fol x Var	88	2618	0.911
Fol x Man	88	2618	0.886
Var x Man	88	2618	0.079
Fol x Nrate	88	3702	0.167
Var x Nrate	88	3702	0.051
Man x Nrate	88	3702	0.135
Fol x Var x Man	88	3702	0.744
Fol x Var x Nrate	88	5236	0.753
Fol x Man x Nrate	88	5236	0.952
Var x Man x Nrate	88	5236	0.111
Fol x Var x Man x Nrate	88	7404	0.910

3.4. Discussion

3.4.1. Economic optimum N rate

There were no differences detected in the economically optimum N rate between Excalibur and PR45D03, due to Canopy Management or due to Folicur in any of the experiments. This was despite differences in the components of yield (seed size and seeds/m^2) between the variety types. At Terrington and Rosemaund in 2008/9, PR45D03 produced significantly ($P<0.001$) more seeds than Excalibur (12% and 11% more seeds/m^2, respectively), and at all sites in 2008/9 and Thornholme in 2009/10 it had significantly lower thousand seed weight, with reductions of 2.5% to 7.6% relative to Excalibur. The small seeds of PR45D03 indicate that higher yields could be achieved by providing better seed filling conditions. Seed yield, total biomass and total N uptake for the two variety types were similar and it is likely that these characteristics are more important for determining optimum N rate than differences in crop height.

3.4.2. Canopy management

In 2008/9, soil and crop N measured in February was low at all three sites (Table 100). In 2009/10, although the canopies at all three sites were moderate to large before winter, they were reduced by the unusually cold winter weather. Consequently, the canopies measured in February were very small at Terrington and moderate at Thornholme and Rosemaund (Table 101). Therefore, in all experiments the differences in N management between Conventional and Canopy Managed treatments were not as great as they have been in some previous experiments. When SNS is low, it is necessary to apply some early N to the Canopy Managed treatments to allow sufficient time for the crop to take up all the N required to build an optimum sized canopy. This means that the differences in N timing between the Canopy Managed treatments and the Conventionally managed treatments is smaller particularly at the lower N rate treatments.

In 2008/9 Canopy Management did not affect yield at any of the three sites (Table 100). In February the canopies were small, and Canopy Management did not affect the growth up to flowering. There was no evidence that over-large canopies were achieved at flowering with the Conventional N timings, with the largest canopy being at Rosemaund, with GAI 3.2. There were also no significant differences in light interception or reflection at flowering, between Canopy Managed and Conventional treatments in 2008/9. The observation that Canopy Management did not significantly reduce the yield of the semi-dwarf variety (Table 100), even in crops with very small canopies, indicates that Canopy Management is appropriate for semi-dwarf varieties and may increase the yield of semi-dwarfs when canopies following winter are large.

Table 100. 2008/9 experiment summary.

	Terrington		Mowthorpe		Rosemaund	
Jan/Feb soil mineral N (kg/ha)	34		34		26	
Jan/Feb additionally available N (kg/ha)	17		75		26	
Jan/Feb crop N content (kg/ha)	12		3		22	
Jan/Feb GAI	0.25		0.09		0.57	
N timing strategy	Conv	CM	Conv	CM	Conv	CM
Optimum N rate (kg/ha)	253	253	244	244	209	209
N rate at 1st split (end Feb/early March)	126	60	122	60	104	60
N rate at 2nd split (early stem ext.)	125	155	122	184	105	149
N rate at 3rd split (yellow bud to mid flower)	0	38	0	0	0	0
Yield at opt N Excalibur (t/ha)	4.19	4.04	4.58	4.45	5.21	5.22
Yield at opt N Excalibur + Folicur (t/ha)	4.34	4.26	4.59	4.59	5.02	5.08
Yield at opt N PR45D03 (t/ha)	4.25	4.20	4.30	4.26	5.59	5.53
Yield at opt N PR45D03 + Folicur (t/ha)	4.34	4.34	4.28	4.27	5.04	5.05

Conv – conventional N timing strategy; CM – Canopy Managed N timing strategy.

Additionally available N (AAN) is an estimate of the amount of N that will become available for crop uptake through mineralisation between February and crop maturity.

In 2009/10, Canopy Management did not affect yield of either Excalibur or PR45D03 at any of the three sites (Table 101). This season provided a robust test for the Canopy Management approach because the uptake of later Canopy Management N applications were delayed by the dry spring and the third N application was applied later than planned at Thornholme. N uptake by OSR crops has been shown to slow after flowering therefore there is a risk associated with applying N too late. At Thornholme the 3rd N split was applied when PR45D03 was beginning to flower and Excalibur was in full flower. At Rosemaund the crop was less advanced when the 3rd split was applied, but the application was preceded by several days of dry weather and followed by a further two weeks without rain, so much of the applied N may not have been available to the crop until well into flowering. However, at both sites the differences between timings in final crop N content were not significant, and there was evidence of continued N uptake after flowering of up to 58 kg/ha in the the higher N rates applied at Canopy Managed timings.

The only site at which over-large canopies were achieved at flowering in 2009/10 was Rosemaund, which averaged GAI 5.45 for the Conventional N timings (N rate 240 kg N/ha) compared to 4.70 for the Canopy Managed timings. Although the difference in GAI was not significant, Canopy Management did significantly reduce the amount of light intercepted by the canopy. This led to a small, but non-significant yield increase of 0.2 t/ha for Excalibur (Table 101). At Thornholme there was a significant reduction in GAI and the amount of light intercepted and reflected by the canopy due to the Canopy Management strategy. These effects did not increase yield because the GAI for the Conventional N timings were less than the optimum. Importantly Canopy Management did not reduce yield. The small canopy at Terrington meant that the crop did not respond to Canopy Management.

Table 101. 2009/10 experiment summary.

	Terrington		Thornholme		Rosemaund	
Jan/Feb soil mineral N (kg/ha)	18		38		14	
Jan/Feb additionally available N (kg/ha)	31		59		25	
Jan/Feb crop N content (kg/ha)	13		49		54	
Jan/Feb GAI	0.24		0.9		1.12	
N timing strategy	Conv	CM	Conv	CM	Conv	CM
Optimum N rate (kg/ha)	228	228	215	215	176	176
N rate at 1st split (end Feb/early March)	114	60	107	40	88	40
N rate at 2nd split (early stem ext.)	114	168	108	107	88	136
N rate at 3rd split (yellow bud to mid flower)	0	0	0	68	0	0
Yield at opt N Excalibur (t/ha)	3.47	3.47	4.98	4.85	4.78	4.98
Yield at opt N Excalibur + Folicur (t/ha)	3.73	3.70	5.20	5.17	5.54	5.61
Yield at opt N PR45D03 (t/ha)	3.50	3.64	5.00	5.07	4.89	4.78
Yield at opt N PR45D03 + Folicur (t/ha)	3.72	3.83	4.98	5.08	5.52	5.51

Conv – conventional N timing strategy; CM – Canopy Managed N timing strategy.

Additionally available N (AAN) is an estimate of the amount of N that will become available for crop uptake through mineralisation between February and crop maturity.

Several components of the Canopy Management principles developed by Berry and Spink (2009) and Lunn *et al.* (2001) and used in the GrowHow 'N-Calc' fertiliser recommendation system were shown to be applicable for semi-dwarf varieties as described below. The requirement for the crop to take up 50 kg N/ha to build each unit of GAI was shown to hold true for both standard height and semi-dwarf hybrids (Figure 3). At flowering PR45D03 produced a larger GAI than Excalibur at two sites with no differences at the other four sites. PR45D03 intercepted more light than Excalibur at one site, with no difference at the other sites. The relatively small differences in GAI and light interception between the varieties indicates that the optimum GAI for intercepting the majority of incoming light will be the same for both varieties. Across the six sites there were no significant differences for the efficiency with which the two varieties took up the soil mineral N (SMN) that was measured in February or the applied fertiliser N. There was a strong positive relationship between the amount of N taken up by the crop in the absence of fertiliser and the amount of SMN and crop N measured in February (Figure 4a). It was apparent that the unfertilised crops generally took up more N than the combined SMN plus crop N measured in February. On average the crops took up an additional 36 kg N/ha. Previous research has shown that the amount of N taken up by unfertilised crops was similar to the amount of SMN plus crop N (Berry and Spink, 2009). The difference between these two studies is likely to have been caused by the experimental sites in this current study having soils with a greater potential for mineralisation between February and crop maturity. When an estimate of the amount of mineralisation (referred to as additionally available N – AAN) was added to the February SMN and crop N, then the prediction of the amount of N taken up by the unfertilised crops was improved (Figure 4b). The fertiliser uptake efficiency was calculated for the 240 kg N/ha fertiliser rate by dividing the difference in crop N uptake at crop maturity between the unfertilised crop and the crop fertilised at 240 kg N/ha by the fertiliser rate. This showed that across the six sites there was no significant difference in fertiliser uptake efficiency between the variety types and the average uptake efficiency was 47%. This fertiliser uptake efficiency is lower than found by Berry and Spink (2009) who estimated an average uptake efficiency of 57% at the N rates closest to the economic optimum N rate (average of 169 kg N/ha). There are two possible reasons for this difference; 1) in this study the N uptake efficiency was calculated for 240 kg N/ha which was, on average, 19 kg N/ha greater than the economic optimum N rate, and it is known that N uptake efficiency decreases at higher N rates, 2) the very dry spring in 2010 reduced N uptake efficiency. The average uptake efficiency in 2010 was 41% compared with 53% in 2009.

This report indicates that both the standard height and semi-dwarf variety types take up N with similar rates of efficiency, require the same amount of N to build each unit of GAI and have a similar optimum GAI target. This indicates that both variety types will require the same amount of fertiliser to achieve optimum GAI and supports the observation that there was no difference in the economic N rates between the variety types.

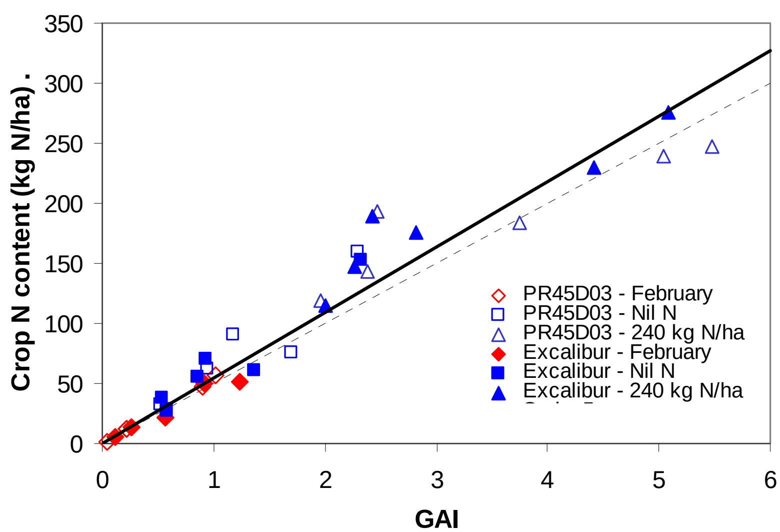


Figure 3. The relationship between Crop N content (kg N/ha) and Green Area Index (GAI) of varieties PR45D03 and Excalibur when measured in February and at mid flowering (Nil N and 240 kg N/ha) in the growing seasons 2008/9 and 2009/10. The bold line is the fitted relationship and the dotted line is the expected relationship (1 unit GAI = 50 kg N/ha).

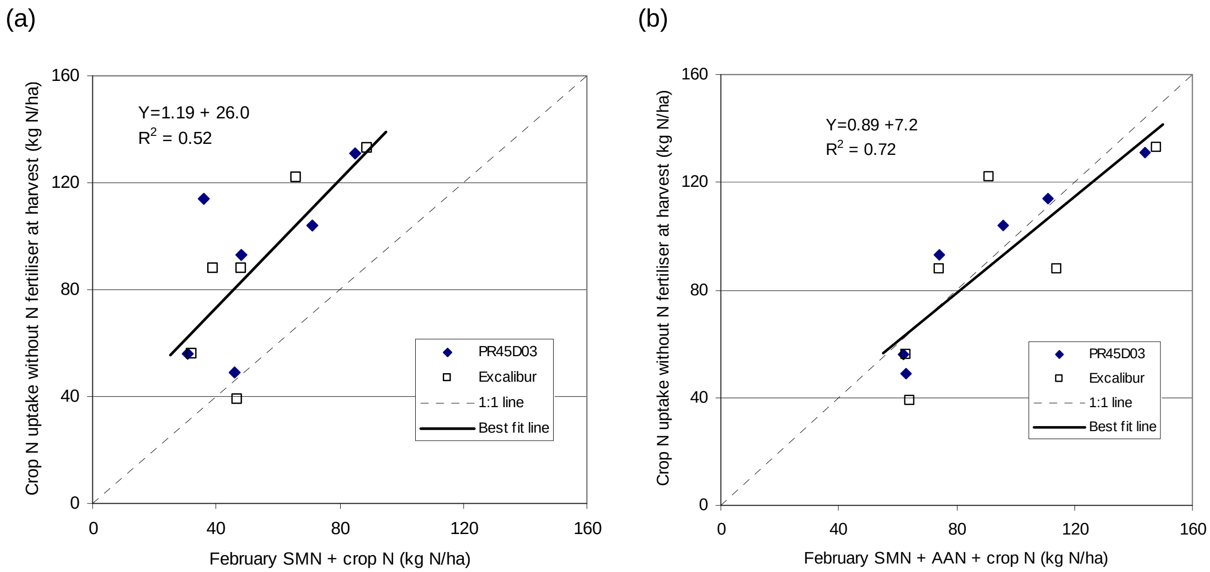


Figure 4. Relationship between a) February SMN + crop N and the amount of N taken up by unfertilised crops by harvest and b) February SMN + additionally available N (due to mineralisation + crop N and the amount of N taken up by unfertilised crops by harvest. Data from each of the 6 experiments carried out within the study.

3.4.3. Crop biomass, N uptake and N residues following harvest

At harvest there was no difference in total crop biomass measured at 240 kg N/ha between Excalibur and PR45D03 at any of the sites (Figure 5). Across all sites the average crop biomass for Excalibur was 12.4 t/ha compared with 11.9 t/ha for PR45D03. PR45D03 had an average stem biomass of 3.75 t/ha which was significantly less than Excalibur at 4.52 t/ha (Figure 5b). The reduction in stem biomass was less than may have been expected given that the height of PR45D03 was on average 33 cm (25%) shorter. Longer branches from the bottom of the semi-dwarf main stems may have partially compensated for the shorter main stems. There was no significant difference in the biomass of the pod walls with both varieties averaging 4.01 t/ha across the six sites.

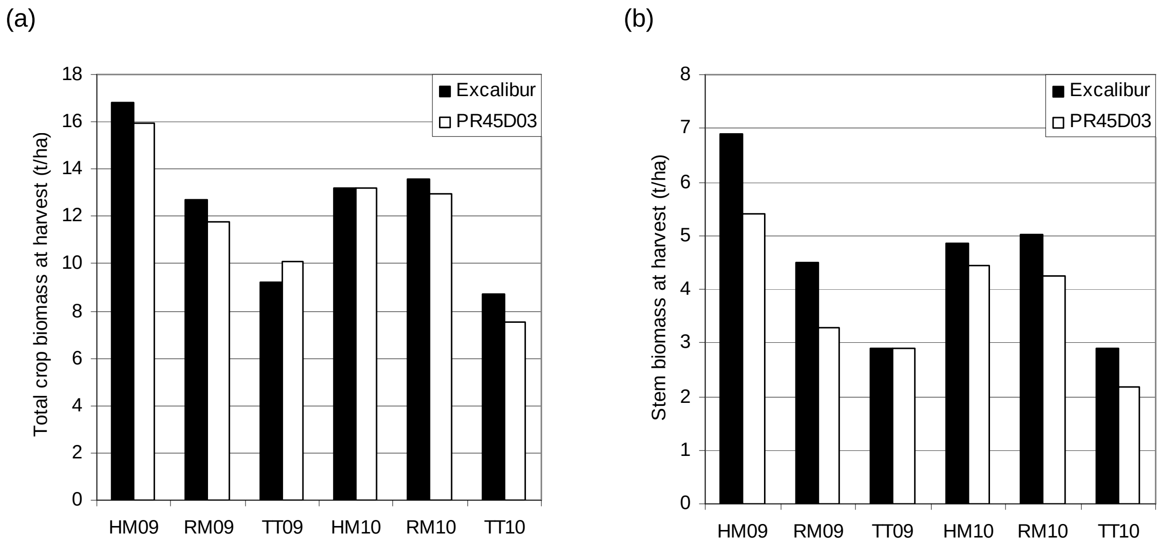


Figure 5. a) Total biomass at harvest; b) stem biomass at harvest. All measurements for the 240 kg N/ha treatment without Folicur. HM – High Mowthorpe, RM – Rosemaund, TT – Terrington.

There was no difference between Excalibur and PR45D03 in the total amount of N taken up by the crop at harvest, with both varieties taking up on average 202 kg N/ha at a fertiliser rate of 240 kg N/ha across the six sites. PR45D03 took off 10 kg/ha less N in the seed at High Mowthorpe in 2008/9, but there were no variety differences in N offtake in any of the other five experiments. On average, both varieties took off 123 kg N/ha in the seed and both left a similar amount of N in the crop residues of approximately 75 kg N/ha. At two sites the stem and pod residues of PR45D03 had a significantly greater tissue N concentration than Exalibur which compensated for the lower stem biomass in terms of the N residues following harvest. These results indicate that the N residues following semi-dwarf oilseed rape are not different from standard height varieties.

3.4.4. Folicur

Effects of Folicur differed between the two seasons. In 2008/9 Folicur at 0.5 l/ha increased yield of both Excalibur and PR45D03, on average, by 0.15 t/ha at Terrington but did not affect yield at High Mowthorpe, and reduced the yield of PR45D03 by 0.51 t/ha and the yield of Excalibur by 0.16 t/ha at Rosemaund. In contrast, in 2009/10, Folicur application significantly increased yield at all three sites, by an average of 0.22 t/ha at Terrington, 0.67 t/ha at Rosemaund, and at Thornholme it increased the yield of Excalibur by 0.27 t/ha and had no effect on PR45D03. It should be recognised that all experimental sites, apart from Rosemaund 2009/10, had a GAI in January/February of less than one (the threshold above which spring PGRs are normally recommended). In 2008/9 the average GAI in January/February across the three sites was 0.30 and in 2009/10 the average GAI was 0.75. The greater GAI in 2009/10 helps to explain the greater yield increases in this season. The yield responses to Folicur were not affected by use of Canopy Managed N timings compared with Conventional N timings.

The greatest yield response to Folicur was at Rosemaund in 2009/10. This effect was likely to be because this site had the largest GAI in January/February (1.12) and at flowering (4.7 to 5.5) which was significanty above the optimum GAI at flowering of 3.5. The significant yield increase for PR45D03 at this site indicates that semi-dwarfs will respond positively to PGRs when canopies are large. The most likely mechanism for the yield increases was the significant reduction in light reflection from the flowers that was caused by Folicur. This would have allowed more light to reach the photosynthetic tissues, thereby allowing more photosythesis during the critical period when the number of seeds were set. Folicur also reduced the amount of leaning at Rosemaund, particularly in Excalibur, although the relatively low levels of leaning which occurred were not likely to have influenced yield significantly. It is worth noting that this reduction in leaning occurred in the absence of any height response to Folicur, at Rosemaund or at the other sites in 2009/10, which indicates that Folicur may have reduced leaning by affecting the architecture of the canopy.

Disease was minimised in all experiments by using fungicides without PGR activity. However, it is impossible to rule out the possibility that part of the yield increases from Folicur were through improved disease control.

The yield reduction following Folicur application at Rosemaund in 2008/9, was likely to have occurred because even without the PGR the GAI at flowering was below the optimum for yield, and Folicur reduced this yet further causing a reduction in light interception during the seed setting period and consequently yield. This hypothesis is supported by the observation that the reduction in yield was due to a reduction in seed number, rather than seed size. It should be noted that the GAI at the start of stem extension was 0.57 and PGRs would not normally be recommended for crops with a GAI of less than 1.

In five of the six experiments, Folicur treatment reduced the fraction of light intercepted by the flowers and/or reduced the amount of light reflected by the flowers of the standard height and semi-dwarf varieties. This shows that Folicur reduced the size of the flower layer, which for over-large canopies will help the crop set more seeds/m^2. This study has shown semi-dwarfs have the potential to produce over-large canopies which indicates that they will respond positively to PGRs.

3.5. Conclusions

- Across the six experiments the semi-dwarf variety PR45D03 had an avarge height of 101 cm compared with 134 cm for Excalibur.
- It was shown that Excalibur and PR45D03 had the same economic optimum N rates and produced similar yields.
- Canopy Management N timings gave the same yield as earlier Conventional N timings for the semi-dwarf and standard height varieties.
- Similar to standard height varieties, semi-dwarfs were shown to also have the potential to produce over-large canopies at flowering which would reduce the number of seeds set and yield potential. This indicates that Canopy Management N timings could increase the yield of semi-dwarfs when they have canopies following winter that are at risk to becoming over-large.
- It was shown that the Canopy Management principles used for standard height varieties also apply for semi-dwarf varieties. These include a similar soil and fertiliser uptake efficiency, the crop must take up 50 kg N/ha to build each unit of GAI and a similar optimum GAI at flowering.
- The experiments provided further evidence that the Canopy Management approach has been successfully adapted for crops with small canopies following winter, such that there is no yield penalty from delaying some of the N until yellow bud / early flowering.
- The semi-dwarf variety took up a similar amount of N and contained a similar amount of N in the seed to the standard height variety. There is therefore no evidence that the N residues remaining after harvest differ for semi-dwarfs.
- There was no difference in N use efficiency between the semi-dwarf and standard height variety as both varieties yielded similarly at a range of N rates including the economic optimum rate.
- At harvest, the overall biomass of PR45D03 averaged 11.9 t/ha compared to 12.4 t/ha for Excalibur. This difference was not statistically significant.
- In the one experiment where an over-large canopy was produced it was shown that Folicur significantly increased the yield of the semi-dwarf variety, which indicates that semi-dwarfs will respond positively to PGRs when canopies are large.
- Folicur was shown to increase seeds/m^2 by increasing the amount of light that penetrated through the flowering layer.
- There may be an opportunity to maximise yields of PR45D03 by focusing on seed filling conditions. PR45D03 generally produced higher seed numbers than Excalibur, but lower seed weight.

4. REFERENCES

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APPENDIX 1. SITE DETAILS 2008/9

Site	**ADAS Terrington**
Field name:	Pips Heavy Field
Soil texture:	Silty clay loam
Sowing date	30/09/08
Harvest date:	04-05-08-09
Previous cropping	
Harvest year	
2008	W Wheat
2007	Peas
2006	W Wheat
Soil analyses 23/10/08	pH 8.1 P 14.6 mg/l (index 1) K 264 mg/l (index 3) Mg 128 mg/l (index 3) OM 3.1
Fertilisers (N, P, K, S)	
09/03/09 (blocks 1-2) 11/03/09 (blocks 3-4)	1st N split
03/04/09	2nd N split
15/04/09	3rd N split
15/04/09	Kieserite 75 kg/ha + TSP 120 kg/ha
Herbicides	
20/11/08	Aramo 1.0 l/ha
Fungicides	
20/11/08	Capitan 25 0.6 l/ha
14/04/09	Folicur 0.5 l/ha to half plots

Site	High Mowthorpe
Field name:	Home Flats, Towthorpe
Soil texture:	Silty clay loam over chalk
Sowing date	26/09/08
Previous cropping	
Harvest year	
2008	W Barley
2007	W Wheat
2006	W Oilseed rape
Soil analyses Nov 08	
	pH 7.9 P 24.8 mg/l (index 2) K 147 mg/l (index 2-) Mg 50 mg/l (index 2) OM 3.6%
Fertilisers (N, P, K, S)	
11-12/03/09	1st N split
01/04/09	Kieserite 150 kg/ha
09/04/09	2nd N split
12/05/09	3rd N split
Herbicides	
04/09/08	Shadow (DOSE)
20/09/2008	Trifluralin 2.0 l/ha
04/11/2008	Kerb 1.8 l/ha
22/03/2009	Galera 0.4 l/ha
Insect/molluscicides	
20/09/2008	Hallmark 0.05 l/ha
04/11/2008	Alert 0.1 l/ha
03/05/2009	Hallmark 0.08 l/ha
Fungicides	
10/04/09	Harvesan 0.4 l/ha
23/04/09	Folicur 0.5 l/ha to half plots
03/05/09	Compass 2.4 l/ha

Site	**ADAS Rosemaund, Fawley Court**
Field name:	Brinkley Hill South
Soil texture:	Sandy loam
Sowing date	15/09/08
Harvest date:	03/08/09 and 06/08/09
Previous cropping	
Harvest year	
2008	W Wheat
2007	W Oats
2006	W Wheat
Soil analyses	
	pH 6.3 P 25.4 mg/l (index 2) K 122 mg/l (index 2-)
Fertilisers (N, P, K, S)	
15/01/09	0:10:40 200 kg/ha
13/03/09	Kieserite 151 kg/ha
25/02/09	First N split
20/03/09	Second N split
08/04/09	Third N split
Herbicides	
29/11/09	Kerb Flo 2.0 l/ha
Fungicides	
29/11/08	Harvesan 0.75 l/ha
20/04/09	Amistar 0.7 l/ha + Proline 0.5 l/ha
04/04/09	Folicur 0.5 l/ha to half plots

APPENDIX 2. SITE DETAILS 2009/10

Site	**ADAS Terrington**
Field name:	Larges, Edgars
Soil texture:	Silty clay loam
Sowing date	25/08/09
Harvest date:	09/08/10
Previous cropping	
Harvest year	
2009	W Wheat
2008	Peas
2007	W Wheat
Soil analyses	pH 8.2 P 8.0 mg/l (index 0) K 231 mg/l (index 2+) Mg 96 mg/l (index 2) OM 2.6%
Fertilisers (N, P, K, S)	N as applied per protocol
10/03/2010	P.Curser (P) @1.0 l/ha
Herbicides	
13/10/2009	Aramo @ 1.0 l/ha
	Springbok @ 2.5 ll/ha
Fungicides	
10/03/10	Capitan 25 @ 0.6 l/ha
24/04/09	Folicur @ 0.5 l/ha to half plots
Dessicant	
21/07/2010	Glyphosate @ 4.0 l/ha
21/07/2010	Companion Gold 1.0 l/ha

Site	ADAS High Mowthorpe
Field name:	Henry's Field
Soil texture:	Silty clay
Sowing date	11/09/09
Harvest date:	06/08/10
Previous cropping	
Harvest year	
2009	W Barley
2008	S Barley
2007	W Wheat
Soil analyses	pH 6.3 P 13 mg/l (index 1) K 136 mg/l (index 21) Mg 72 mg/l (index 2)
Fertilisers (N, P, K, S)	N as applied per protocol
13/04/2010	Keiserite (150 kg/ha)
Herbicides	
11/09/2009	Pilot Ultra @ 0.4 l/ha
	Shadow @ 2.3 ll/ha
	Dictate @ 0.2 l/ha
Fungicides	
28/10/09	Mirage 40EC @ 0.4 l/ha
28/10/09	Bola @ 1.25 l/ha
16/4/10	Juventus @ 0.6 l/ha
24/5/10	Charisma @ 0.75 l/ha
24/5/10	Topsin WG @ 0.45 l/ha
24/04/09	Folicur @ 0.5 l/ha to half plots
Insecticides	
28/10/09	Alert @ 0.15 l/ha
16/04/10	Alert @ 0.20 l/ha
24/05/10	Mavrik @ 0.20 l/ha
Dessicant/Sealant	
19/07/2010	Glyphosate @ 4.0 l/ha
19/07/2010	Chex 0.3 l/ha

Site	**ADAS Rosemaund**
Field name:	Big Field Ladyridge, Fawley
Soil texture:	Sandy Clay Loam
Sowing date	31/08/09
Harvest date:	05/08/10
Previous cropping	
Harvest year	
2009	Winter Wheat
2008	Winter Barley
2007	Winter Oilseed rape
Soil analyses	
	pH 6.5 P 29.2 mg/l (3) K 137 mg/l (2-)
Fertilisers (N, P, K, S)	
S	Kieserite (75kg/ha [150kg/ha product]) 10/04/10
	Ground Limestone 1t/acre
Herbicides	Oryx 3l/ha
	Cypermethrin 0.25l/ha
	Fusilade Max 0.4l/ha
Fungicides	
10/04/2010	Proline (0.4 l/ha)
26/04/2010	Proline (0.6 l/ha) + Amistar (0.5 l/ha)