PROJECT REPORT No. 337

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PART OF AVIAN FEED EFFICIENCY FROM NAKED OATS (AFENO)

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PART OF AVIAN FEED EFFICIENCY FROM NAKED OATS (AFENO)

by

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ABSTRACT

Advances in plant breeding at IGER, Aberystwyth have led to the establishment of naked oats as a viable break crop option for growers and advanced varieties of 'high oil' naked oats offer the potential for significantly enhanced performance in monogastric diets.

Oats are a cereal break crop option for growers. However the relatively modest annual production is constrained by the lack of viable markets to sustain an attractive return to the grower. The animal feed market has the potential to double the area of oats under production, whilst offering the compounder a starch based high-energy alternative to the high levels of wheat currently used in poultry diets. An increase in the cultivated area of oats would also benefit the environment through encouraging biodiversity together with the advantages of lower fertiliser, herbicide, and pesticide regimes when compared to wheat.

The Avian Feed Efficiency from Naked Oats (AFENO) project was established to conduct a coordinated programme of research to test the advantages of naked oats to the grower as an economic break crop, to the poultry industry as an effective in broiler and turkey rations, and to the consumer in improved meat quality. This report forms the part of the AFENO project report concerned with crop agronomy, which was funded by HGCA.

Yield response to reduced plant densities.

The economic optima were between 82 and 132 plants m^{-2} indicating the possibility to reduce seed rates from current commercial practice. However this is dependent on favourable seeding conditions, date of sowing and the inherent lower germination of naked oats needs to be taken into account.

Effects of reduced plant densities on quality.

Reduction in plant densities gave an increase in thousand grain weight (TGW). There was a positive correlation between protein content and TGW. However oil content reduced with increasing TGW.

Effect of nitrogen timing on grain yield.

In the absence of significant lodging the optimum yield was not affected by nitrogen timing.

Effect of nitrogen rate on grain yield.

Variety, soil fertility and plant population affect the potential for improved yield from increasing nitrogen applications. On average every 1 kg/ha of applied nitrogen increased grain yield by 13 kg/ha. Yield responses from liquid foliar urea as a late-season application were inconsistent.

Effect of nitrogen application on grain nutrient quality.

Nitrogen management provides the grower with a method of manipulating grain quality. However increases in oil were at the expense of protein.

SUMMARY

Aims

To investigate and understand the effects of husbandry techniques on grain quality and nutrient density of naked oats.

To produce grain of a known range of protein and oil contents for feed evaluation to demonstrate their suitability and benefits for inclusion in avian diets. The results of this work are reported in the complete AFENO project report which is available from Oat Services Ltd.

Objectives:

1. To develop an understanding, using close monitoring of crop growth and development, of how crop husbandry techniques affect yield and grain nutrients.
2. To evaluate how growers can use these agronomic techniques to manipulate grain quality whilst maximising their income.
3. To demonstrate that high protein and high oil content naked oats can be produced across the UK using new dwarf and semi-dwarf varieties combined with improved agronomic and crop husbandry techniques.
4. To nutrient profile the resultant grain and produce up-to-date information of oat nutritional value for the animal feed milling and compounding industry.

Methods

In each of three years, three fully randomised and replicated field experiments were carried out at ADAS Rosemaund, Preston Wynne, Hereford. These investigated the effects of a number of agronomic inputs such as variety, seed rate, strobilurin fungicides, applied nitrogen (type, timing and rate) on grain yield and quality. Additional sites in Scotland and the East of England managed by Scottish Agronomy Ltd and SW Semundo Ltd respectively were used to further test the interactions and validate results at different sites. In 2001, a variety x nitrogen/fungicide trial was set-up at Hilton on Fern, Midlothian on spring oats and on winter oats at Caythorpe, Lincolnshire. In 2002, a variety x nitrogen/fungicide trial was set-up at Kirkness, Fife and Abbots Ripton, Cambridgshire both on winter oats. In 2003, a winter oat variety x nitrogen trial was set-up at Abbots Ripton, Cambridgshire only. At all sites in all years plots were drilled with an 'Oyjord type' tractor-mounted seed drill. Plot dimensions were 2m wide by 24m long at the ADAS Rosemaund, 2m wide by 12m long at Scottish Agronomy Ltd and 1.5m wide by 6m long at SW Semundo Ltd. Other than the experimental treatments described crops were grown using standard rates of agrochemicals and fertilisers with an aim to maintain undisturbed and healthy crop growth.

<u>Experiment 1: Variety x seed rate</u>

In 2001, three varieties (Grafton, Icon, Millennium), which represented commercially available varieties at the time, were chosen. Grafton is the leading conventional height naked oat; Icon is the only commercially available dwarf naked oat and Millennium is a thin-husked conventional variety. These varieties were sown at five seed

rates (50, 100, 200, 400 and 800 seeds m-²) in a split plot design with variety as main plots and seed rate as sub-plots each replicated four times.

In 2002, three varieties (Grafton, Lexicon, Hendon), were chosen. Lexicon is a popular conventional height naked oat and Hendon is a new dwarf naked oat. These varieties were sown at three seed rates (200, 400 and 600 seeds m-²). Three different seed lots of each variety from different parent seed crops were used. The experimental design was a split plot plus two way factorial with variety as main plots and seed rate and seed lot as sub-plots each replicated four times.

In 2003, two varieties (Grafton, Millennium), were chosen. These varieties were sown at five seed rates (50, 100, 200, 400 and 600 seeds m-²) in a fully randomised two way factorial design replicated four times.

Experiment 2: Variety typing

In all three years at ADAS Rosemaund a range of varieties were sown at a standard seed rate (400 seeds m^{-2}). The list of varieties tested in each year can be seen in the following table.

Variety	2001	2002	2003
Ayr			✓
Birnam	✓		
Buffalo		✓	✓
Dalguise		✓	✓
Expression	✓	✓	✓
Gerald	✓	✓	✓
Grafton	✓	✓	✓
Harpoon	✓	✓	
Hendon	✓	✓	✓
Icon	✓		
Image	✓		
Jalna	✓	✓	✓
Kingfisher	✓	✓	✓
Krypton	✓	✓	
Lexicon	✓	✓	
Millennium	✓	✓	✓
Viscount	✓		
91-229Cn234 (Chris – high oil)	✓	✓	✓
91-229Cn253 (Fatso – high oil	✓		
93-76Cn1/1	✓		
94-116Cn4/1 (New husked dwarf)		✓	✓
95-205Acn1/2 (Large grained short naked)		✓	
95-56Acn3 (MM/Jalna)	✓	✓	
96-140Cn1 (New high oil)		✓	
95-240Cn 3/1/1/1			✓
95-27 Cn5/1			✓
95-75 Cn5/1			✓

The experimental design was fully randomised block design with four replicates.

Experiment 3: Variety x nitrogen/fungicide

In 2001, three winter naked oat varieties (Grafton, Icon and Hendon) were sown at two seed rates 200 and 400 seeds m^{-2} at two sites Rosemaund and Caythorpe. At Midlothian two spring oat varieties (Bullion and Neon) were sown at the same seed rates.

Three nitrogen treatments with different rates and timings of prilled ammonium nitrate were applied as follows:

	Ammonium Nitrate kg N/ha			Foliar Urea kg N/ha	Total Rate kg N/ha
Trt No.	GS 30	GS 31/2	GS 33/7	GS65	
1	80	0	40	0	120
2	40	40	40	0	120
3	40	40	40	60	180

Three fungicide treatment programmes were applied as follows:

Treatment No.	Product	Rate l/ha	Timing
1	Alto 100 + Corbel	0.4 + 0.5	GS 31/2 & GS 39
2	Mantra	1.0	GS 31/2
3	Mantra	1.0	GS 31/2 & GS 39

The experimental design was a split plot plus three way factorial with varieties as main plots, seed rate, nitrogen and fungicide treatments as randomised sub-plots with three replicates.

In 2002, three winter naked oat varieties (Grafton, Hendon and Expression) were sown at two seed rates 200 and 400 seeds m^{-2} at three sites Rosemaund, Abbots Ripton and Kirkness. Due to poor plant establishment associated with sowing problems the Abbots Ripton site had to be abandoned.

Five nitrogen/fungicide treatments with different type and timings of nitrogen were applied as follows:

Treatment No.	Ammonium Nitrate kg N/ha		Foliar Urea kg N/ha	Fungicide l/ha	
	GS 30/31	GS 32	GS 65	GS31/2	GS 39
1	120	-	-	Alto 100 0.4 Corbel 0.5	Alto 100 0.4 Corbel 0.5
2	40	80	-	Alto 100 0.4 Corbel 0.5	Alto 100 0.4 Corbel 0.5
3	40	40	40	Alto 100 0.4 Corbel 0.5	Alto 100 0.4 Corbel 0.5
4	40	40	60	Alto 100 0.4 Corbel 0.5	Alto 100 0.4 Corbel 0.5
5	40	40	40	Opera 1.0	Opera 1.0

The experimental design was a split plot plus two way factorial with varieties as main plots, seed rate and nitrogen/fungicide treatments as randomised sub-plots with three replicates.

In 2003, three winter oat varieties (Hendon, Buffalo and Millenium) were sown at a single seed rate of 400 seeds m^{-2} at two sites Rosemaund, Abbots Ripton.

Three nitrogen treatments with different rates and timings of prilled ammonium nitrate were applied at Rosemaund as follows:

Treatment	Ammonium Nitrate N kg/ha GS 30	GS 32	Total N kg /ha
1	40	60	100 (RB 209 rec + 30)
2	40	120	160 (RB 209 rec + 90)
3	40	180	220 (RB 209 rec + 150)

Six nitrogen treatments with different rates and timings of prilled ammonium nitrate were applied at Abbots Ripton as follows:

Treatment	Ammonium Nitrate N kg/ha GS 30	GS 32	GS 65	Foliar Urea N kg/ha GS 65	Total N kg /ha
1	40	60	0	0	100 (RB 209 rec - 30)
2	40	90	0	0	130 (RB 209 rec)
3	40	90	0	30	160 (RB 209 rec + 30)
4	40	90	30	0	160 (RB 209 rec + 30)
5	40	120	0	0	160 (RB 209 rec + 30)
6	40	150	0	0	190 (RB 209 rec + 60)

The experimental design was a split plot plus factorial with nitrogen as main plots and variety as randomised sub-plots with three replicates.

Measurements

In the detailed field experiments at ADAS Rosemaund crop establishment was assessed pre-tillering with the number of plants counted in 10m x 1m row lengths per plot. Weekly measurements of light interception with ceptometers (Sunfleck meters) allowed canopy development to be monitored through the growing season. Crop growth assessed as both dry matter and green area index measurements were taken from a sub set of treatments and experiments at stem extension (GS31) and when 50% of all the main shoots reached mid-anthesis (GS65). An assessment of the components of yield was made on samples taken immediately pre-harvest. Grain yield was measured using a plot combine from a harvest area of 10m by 2m. Grain specific weight was measured using a manual chondrometer, grain moisture content was calculated after oven drying at 80^{O}C for 48 hrs. Thousand-grain weight was measured using a numigral grain counter. Grain sub-samples for nutritional analyses were taken and cleaned to industry standard before being sent to DirectLabs for nutrient profiling and larger bulked samples sent to the Roslin Institute for poultry feeding studies.

Key results and conclusions

Plant population

The number of plants established from a given seed rate varied significantly between years, and average plant densities ranged from 46 to 414 plants m^{-2} from the range of seed rates used. Plant populations were lowest in

the first year (autumn 2000), plant densities ranged from a low of 36 plants m^{-2} for Icon sown at 50 seeds m^{-2} to a high of 320 plants m^{-2} for Grafton sown at 800 seeds m^{-2}. Plant establishment averaged across the varieties ranged from 85% at 50 seeds m^{-2} to 37% at 800 seeds m^{-2}. This concurred with findings in wheat (Spink et al, 2000) although on average the rate of decline was greater. This may be explained by the extreme wet weather conditions of autumn 2000 where 402 mm of rainfall occurred between September and December the most since 1960. In year 2 (autumn 2001) where only three seed rates (200, 400 and 600 seeds m^{-2}) were sown, plant densities ranged from 111 plants m^{-2} for Grafton sown at 200 seeds m^{-2} to 378 plants m^{-2} for Hendon sown at 600 seeds m^{-2}. Plant establishment was more typical with higher seed rates at 50%. In year 3 (autumn 2003), plant densities ranged from 48 plants m^{-2} for Grafton sown at 50 seeds m^{-2} to 468 plants m^{-2} for Millennium sown at 600 seeds m^{-2}. Plant establishment averaged across the varieties was highest in this year with 87% at 50 seeds m^{-2} to 69% at 600 seeds m^{-2}; this was due to favourable mild and damp autumn conditions. In years 1 and 3 where both naked and husked varieties were grown lower plant establishment (10 to 20%) was achieved at lower the seed rates in the naked varieties. This may be attributable to the lower germination found in naked oat seed. As long as it taken into consideration by growers when calculating their seed rate it does not preclude the use of lower seed rates in naked oats.

Plant compensation for reduced plant densities

In wheat tiller production primarily through extension of the duration of tillering has been shown to be a key mechanism by which plants compensate for reduced plant densities. Counts of tiller numbers on tagged plants on three seed rates every fourteen days suggests that in oats low seed rates also compensate with increased tiller production and duration (Figure 1). Tiller production averaged across three varieties peaked at 14 tillers/plant on 21 May 2001 for the 50 seeds m^{-2} whereas it was 6 tillers/plant on the 14 April for 800 seeds m^{-2}. By the end of tillering there were 11 tillers/plant from the 50 seeds m^{-2} compared with 3 for the 800 seeds m^{-2}.

Fertile shoot counts assessed from a destructive growth analysis sample at stem extension and at mid-anthesis showed that a 6.4-fold difference in plant density had been reduced to a 2.6 fold difference in shoot number by increased tiller production. This compensation was reduced further by improved tiller survival at reduced populations such that the difference immediately pre-harvest was reduced to 2.4 fold.

Similar compensation was also seen in both year 2 and 3 seed rate trials. In 2002, on average 4.4 tillers/plant were produced from 200 seeds m^{-2} compared with 2.8 from the 800 seeds m^{-2} the differences smaller due to the smaller difference in seed rate. A 2.2 fold difference in plant density was reduced to 1.7 by stem extension and further to 1.4 by mid-anthesis. In 2003, an 8.3 fold difference in plant density was reduced to 1.5 fold difference in panicle numbers immediately pre-harvest.

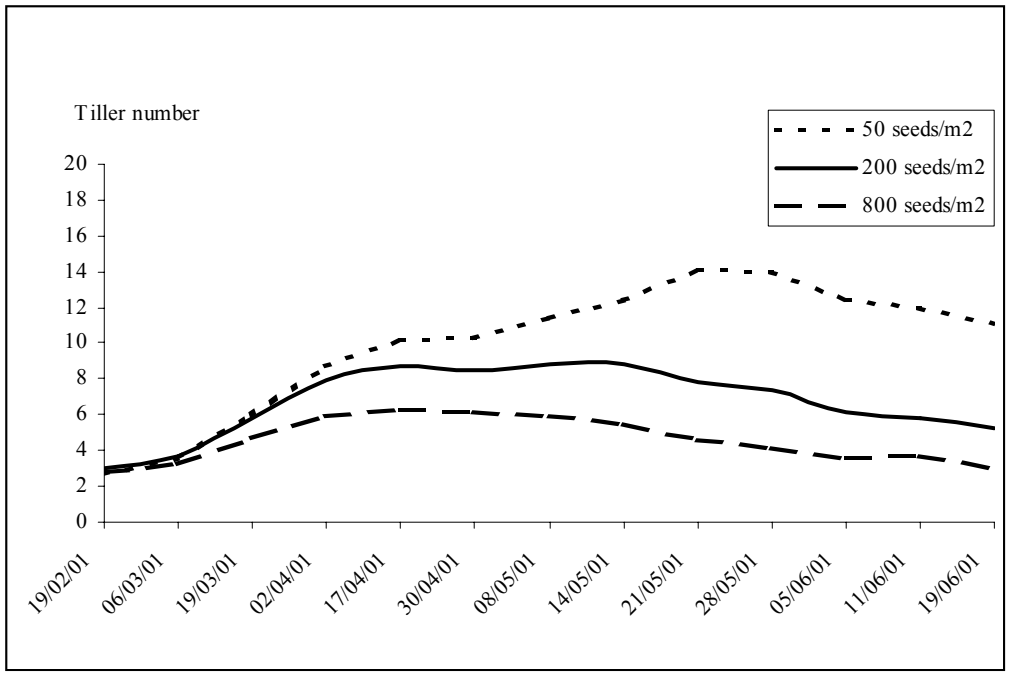

Figure 1. Tiller counts meaned across three varieties at three seed rates in 2001.

Early season measures of variety effects on tiller production showed that Icon in year 1 and Lexicon in year 2 had a greater tillering capacity than the other varieties however the tillers produced were not retained as by later in the growing season the differences were no longer present. Grafton in all years was the least well-tillered variety.

Another compensation method to reduced plant densities seen in other cereals is increased grain number per panicle. In two out of the three years significantly more grain was produced per panicle at low plant densities (figure 2.).

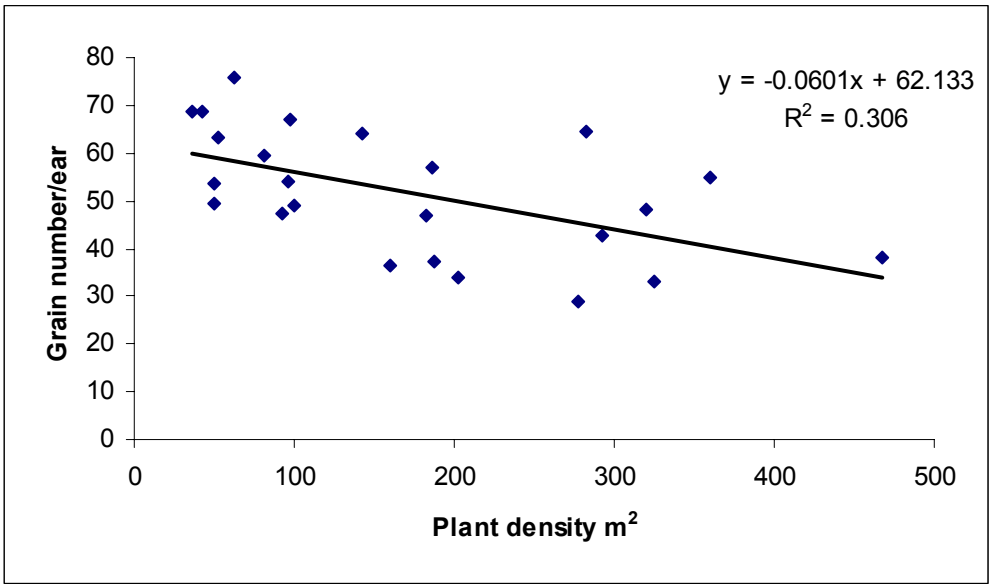

Figure 2. Regression analysis to indicate the relationship between grain number per panicle and plant density (plants m^2) in winter oats from two site seasons.

In 2001, 35% more grain per panicle (p=0.009) was produced as plant density was reduced from 190 to 70 plants m^{-2}. This resulted in a 44% or 0.6g increase in grain weight per panicle for the same reduction in plant density. A smaller but still significant increase (p=0.006) in grain number per panicle of 11% was seen in 2003 when plant density was reduced from 304 to 91 plants m^{-2} and grain weight per panicle increased by 22%.
Variety main effects on grain number per panicle were also significant in two out of three years. In 2001, both Grafton and Icon had significantly (p=0.007) increased number of grains, with average increases of 57 and 39% respectively over Millennium. In 2003, Grafton had 67% more (p=<0.001) grains per panicle than Millennium.

Yield response to reduced plant densities

Yields of naked oat varieties ranged from a low of 2.85 t/ha in Grafton in 2001 to a high of 7.66 t/ha in Hendon in 2002. The husked variety Millennium ranged from 5.37 to 8.66 t/ha in 2001 and 2003 respectively. Initially yield increased rapidly as seed rates increased but slowed once 200 seeds m^{-2} was reached. In 2001, when yields were below average, there was a trend for yields to increase up to the highest seed rates (figure 3.). In 2002 where a reduced number of seed rates was used there was no significant yield increase after 400 seeds m^{-2} was reached. In 2003, where late season lodging occurred in seed rates greater than 100 seeds m^{-2} yield decreased at the higher seed rates particularly in variety Millennium (figure 4.). Using the linear plus exponential curve fits presented in figure 1.3 and 1.4 and a seed cost to grain price ratio of 6:1, economic optimum seed rates were estimated. Optima were 202, 159 and 165 seeds m^{-2} for Grafton, Icon and Millennium respectively in 2001 and 86 seeds m^{-2} for Grafton and Millennium in 2003. Using establishment figures these can be equated in to economic optimum plant populations of 98, 76 and 132 plants m^{-2} for Grafton, Icon and Millennium respectively in 2001 and 82 plants m^{-2} for Grafton and Millennium in 2003. Optima could not be estimated in 2002 with the reduced number of seed rates available. This suggests that there is scope to reduce seed rates in winter oats depending on drilling date and seed bed conditions. However the lower germination in naked oats would need to be taken into account when seed rates were calculated. The reduction of lodging at the reduced seed rates in 2003 indicates an additional benefit to reduced plant densities. Lodging is still seen by many growers as a major problem in oats and so reducing seed rates may be cost-effective way for growers to reducing lodging risk with negligible effect on yield.

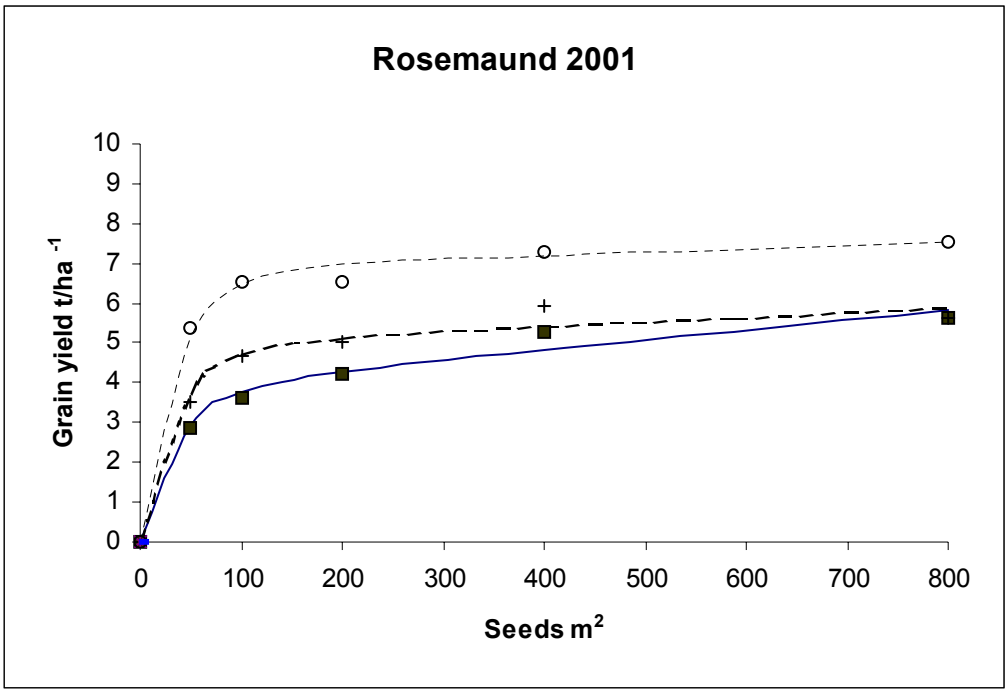

Figure 3. Relationship between seed rate seeds m^{-2} and grain yield t/ha at ADAS Rosemaund. Curve fitted linear plus exponential $Y = a + b(r)^x + cx$. Variety; Grafton (■ fitted curve solid line); Millennium (O fitted curve dashed line); Icon (+ fitted curve broken line).

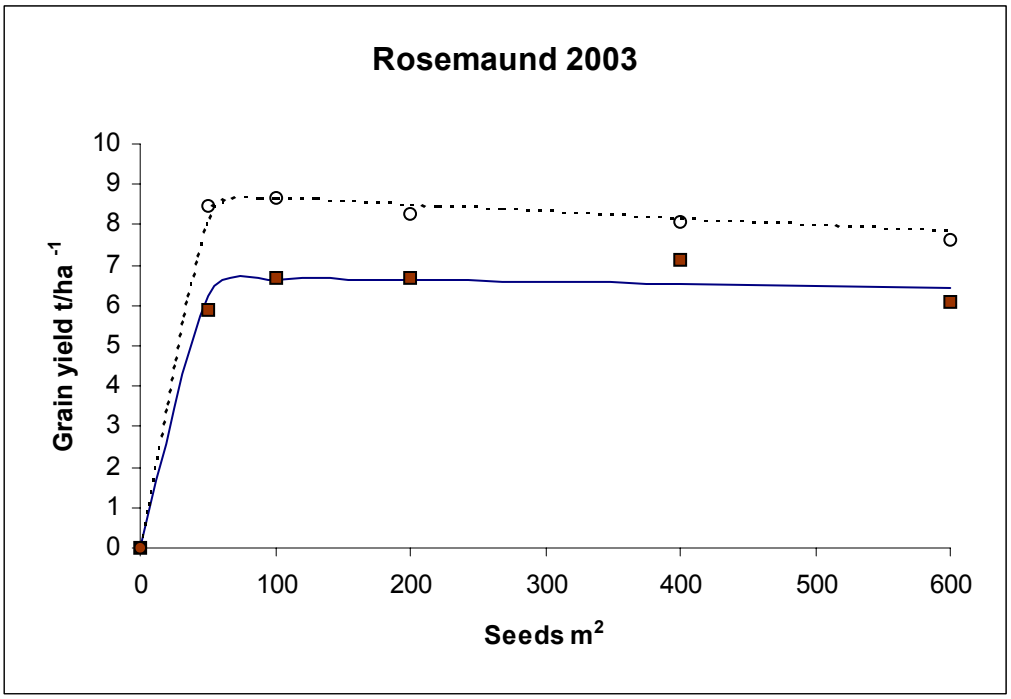

Figure 4. Relationship between seed rate seeds m^{-2} and grain yield t/ha at ADAS Rosemaund. Curve fitted linear plus exponential $Y = a + b(r)^x + cx$. Variety; Grafton (■ fitted curve solid line); Millennium (O fitted curve dashed line).

Effects of reduced plant densities on grain quality

There was a trend for grain size to be increased at reduced plant densities in both 2001 and 2003. Average grain size increased significantly 11 % when plant population was reduced from 297 to 46 plants m^{-2} in 2001. Increases were smaller in 2003 with a 7 % increase in average grain size as plant population was reduced from 414 to 50 plants m^{-2}. These increases were more pronounced in the naked varieties with 15 % and 10 % increases in 2001 and 2003 respectively over the same plant density ranges.

There was an indication that as plant population was reduced and thus thousand-grain weight increased the amount of oil in the grain decreased, indicated by the linear regression presented in figure 1.5. It has been generally accepted that grain oil content is in the main controlled genetically and therefore can only be manipulated by growers by variety choice. However, this data suggests that by growing crops at high seed rates growers may be able to increase to a small degree the oil content of grain. But these increases in oil content are counter balanced by decreases in protein content as plant population is increased and grain size reduced. Even these small increases in oil content may be of value due to its high energy content and therefore feed value but would have to be balanced with the increased cost of production.

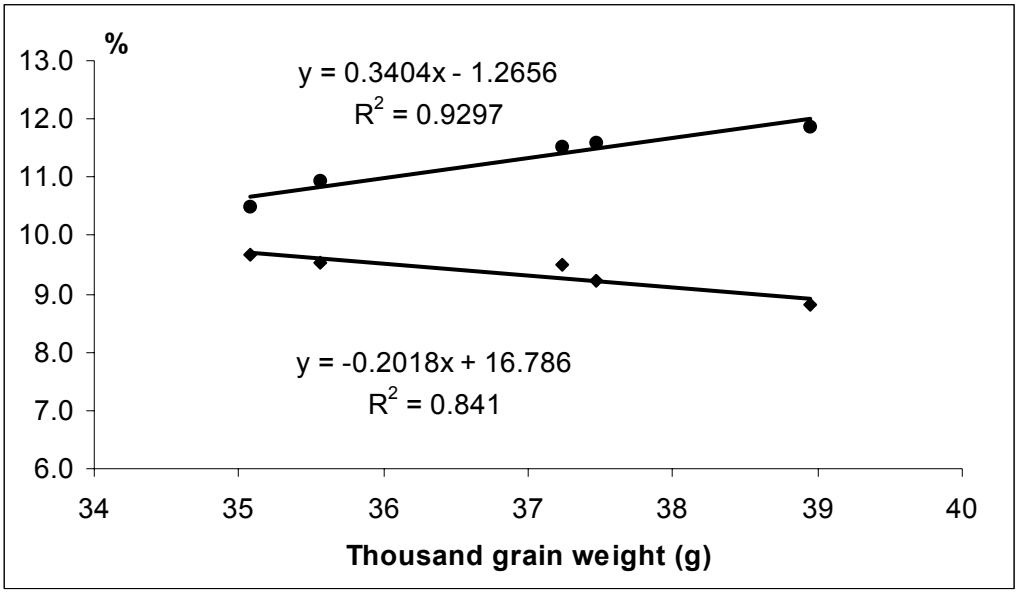

Figure 5. Relationship between thousand grain weight (g) and oil % (◆); thousand grain weight (g) and protein % (●) at ADAS Rosemaund 2001.

Effect of nitrogen timing on grain yield

Grain yield response to timing of nitrogen application was investigated in year 2. At both sites Rosemaund and Kirkness no significant differences were found in grain yield. The greatest yield response compared to the 120 kg/ha single application at Rosemaund was 0.26 t/ha for the 40 plus 80 kg/ha two split treatment and the corresponding treatment comparison at Kirkness resulted in a 0.18 t/ha yield response. As a result on average across the three naked oat varieties and two seed rates this two split 40 plus 80 kg/ha nitrogen application gave a yield of 6.88 t/ha. The yield responses to late applications of foliar urea were greatest at the Scottish site with a 0.15 t/ha increase from a 60 kg/ha application at GS65 but at Rosemaund there was little yield response to foliar

urea. This data suggests that in the absence of significant lodging optimum yield in winter oats is relatively independent of the timing of the nitrogen application but a split application at GS30/1 and GS32 is likely to maximise yield.

Effect of nitrogen rate and type on grain yield

In the absence of significant lodging in 2001 trials, grain yield increased significantly as rate of applied nitrogen was increased. Yield responses were greatest in the spring oat trial in Midlothian, a 30 kg increase in nitrogen from 70 to 100 kg/ha produced a 0.5 t/ha mean yield increase (p=<0.001). At Caythorpe an increase of 60 kg from 60 to 120 kg/ha produced a mean yield increase of 0.27 t/ha (p=<0.001). Both trials in 2002 and the Rosemaund trial in 2001 treatments were designed to investigate the effects of nitrogen timing and are discussed in the previous section. At both Rosemaund and Abbots Ripton sites in 2003 mean grain yield increased with increasing nitrogen rate up to 160 kg/ha of applied nitrogen after which there was a decrease. At Rosemaund this was caused by significant levels of lodging in all treatments but at its worst in the highest applied nitrogen treatment. Average lodging scores recorded on 29 July were 26, 37 and 56 % for 100, 160 and 190 kg/ha respectively. The lodging resistant dwarf varieties Hendon and Buffalo also lodged in the trial which was intended to test lodging resistance at high applied nitrogen levels. This suggests that variety, soil fertility, plant population should all be taken into consideration when planning nitrogen strategy to optimise yield. On average across seven site seasons for every 1 kg/ha of applied nitrogen there was an increase of 13 kg of grain. There was a trend for yield to increase rapidly up to 125 kg/ha of applied nitrogen but slowed thereafter.

Yield responses to the use of liquid foliar urea as a late season nitrogen application was inconsistent. In 2001 they were positive at all sites, 0.07, 0.11 and 0.18 t/ha from Midlothian, Caythorpe and Rosemaund respectively. At both Kirkness and Rosemaund in 2002 yield responses were negative -0.15 and -0.3 t/ha respectively compared with a comparative two split solid treatment. At Abbots Ripton in 2003 a GS65 foliar urea treatment was compared with a solid nitrogen treatment at the same timing. The solid nitrogen gave an average yield of 7.38 t/ha compared to the liquid at 7.10 t/ha.

Effect of nitrogen applications on grain nutrient quality

Chemical analysis of the grain using the acid hydrolysis method was used to determine oil levels. Results showed a significant effect of nitrogen application timing on grain oil content at Rosemaund in 2001 (p=<0.001) and 2002 (p=0.027) (figure 6.).

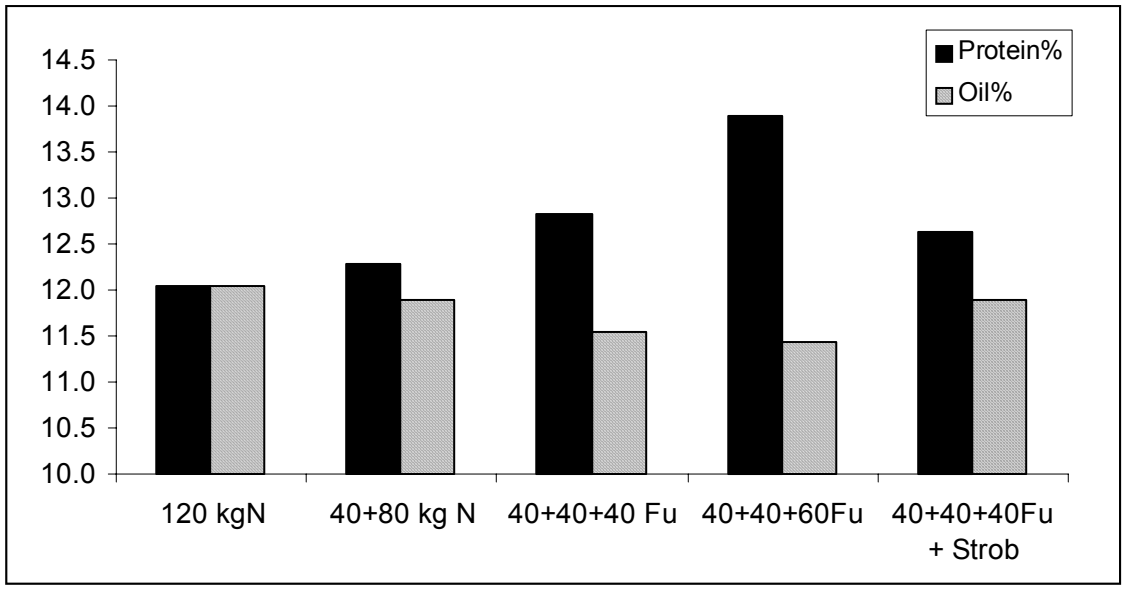

Figure 6. Effect of nitrogen application timing on protein (%) and oil (%) in grain from Rosemaund in 2002.

In general this indicated that early applications of nitrogen maximised oil content. This was supported by data from the Kirkness trial in 2002 where the highest oil levels of 10.62 and 10.88% were achieved from the 120 kg/ha single application and 40 plus 80 kg/ha split application respectively (p=0.007). However protein levels calculated from Leco nitrogen % multiplied by 6.25 showed that early nitrogen application treatments were lower from those that contained late applications of foliar urea. In 2001, foliar urea treatments significantly increased protein levels over two split solid nitrogen applications by 1.1, 1.2 and 1.8 % at Midlothian, Rosemaund and Caythorpe respectively. At Rosemaund in 2002 the same comparison of treatments significantly increased protein by 1.62 %. But at the Kirkness site in 2002 no significant increases in protein content with late nitrogen applications were detected.

Results suggest that nitrogen management provides growers with a way of manipulating grain nutrients. But increases in oil content are at the expense of grain protein suggesting that there is a degree of substitution of protein when oil is deposited in the grain and therefore have to be balanced to maximise feed value. The higher calorific value of oil suggests that this should be the target for poultry production

Variety developments in grain yield

A range of varieties were assessed in all three years to establish the genetic developments in grain yield of both naked and husked cultivars. Yields for naked varieties ranged from 3.42 for experimental high oil line Fatso in 2001 to 8.29 t/ha for Expression in 2002. Husked variety yields ranged from 6.35 t/ha for Birnam in 2001 to 10.29 t/ha for Kingfisher in 2002.

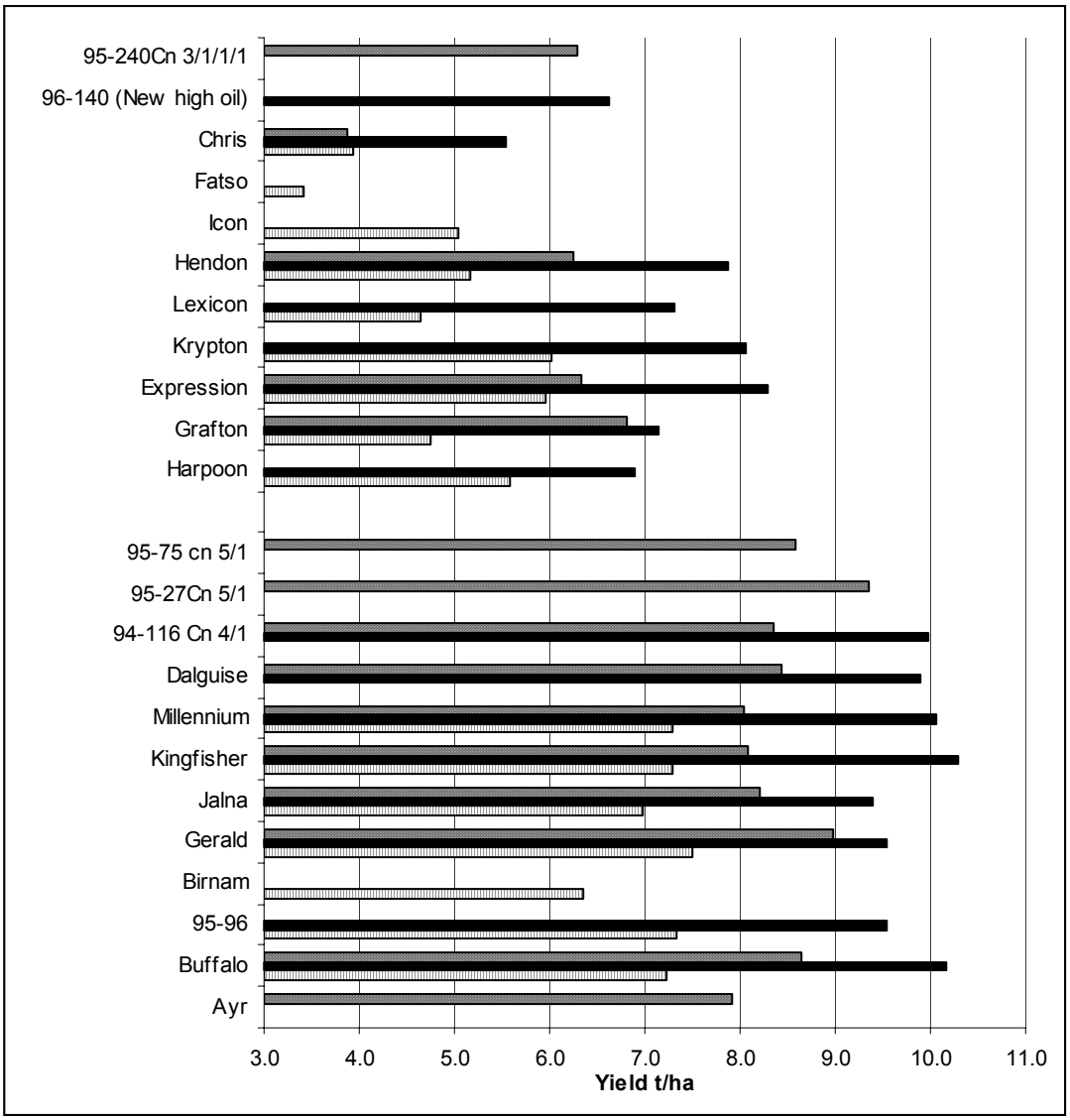

Figure 7. Variety effects on grain yield t/ha at Rosemaund in three years, 2001 (vertical stripes), 2002 (solid bar), 2003 (diagonal stripe).

Husked varieties	Dalguise, Millennium, Kingfisher, Jalna, Gerald, Birnam, 95-96, Buffalo, Ayr.
IGER experimental Husked varieties	95-75,Cn5/1, 95-27Cn5/1, 94-166Cn4/1.
Naked oats	Icon, Hendon, Lexicon, Krypton, Expression, Grafton.
IGER experimental Naked oat varieties	95-240Cn3/1/1/1/1, 96-140.

TECHNICAL DETAIL

Introduction

Traditional animal feed usage of oats has been on farm feeding as a valuable concentrate for cattle and sheep with little usage by feed compounders. The high fibre content of husked oats, which reduces digestibility and dilutes the concentration of other nutrients, has limited use to ruminants and horses which have the capacity to digest fibre (Cuddeford, 1996). Advances in plant breeding at IGER, Aberystwyth had led to the development of naked oats. Naked oats thresh clear from the husk and are thus highly digestible. Studies have shown that naked oats are particularly suited to non-ruminants, especially poultry, which have a limited ability to cope with fibre (Bolton & Blair, 1974; Valentine & Clothier, 1992). Considerable commercial interest had been expressed in investigating the use of oats in poultry rations, as birds fed commercially on oat diets appeared to perform better than expected from the nutritional description of oat grain.

Oats offer the grower a viable cereal break crop with a low demand for input. They are resistant to the main strain of take-all affecting wheat or barley (*Gaeumannomyces graminis var tritici*) and therefore offer a take-all break. They have naturally high foliar disease resistance and good nitrogen utilisation thus have a lower requirement in chemical and energy inputs. Recent advances in plant breeding producing higher yielding lodging resistant varieties have left oats well placed to fit into the rotation of a sustainable farming system. However the relatively modest annual UK production is constrained by the lack of viable markets to sustain an attractive return to the grower. The animal feed market has the potential to double the area of oats under production, whilst offering the compounder a starch based high-energy alternative to the high levels of wheat currently used in poultry diets. To maximise this new potential market for the growers and assure continuity of supply for the compounder naked oats would have to be grown using agronomic management that maximises return to the grower by optimising cost of production and output whilst maintaining nutritional grain quality desired by the poultry industry end-user. This paper describes field trials used to investigate agronomic management techniques (seed rate, variety, nitrogen rate and timing) that could be used to balance optimisation of output, cost of production and nutritional grain quality of oats.

APPENDIX 1

Variety x Seed rate Interaction experiments

Materials and Methods

Experiments were carried out at ADAS Rosemaund, Herefordshire (52.1^{O}N, 2.5^{O}W) in each of three years. In the 2000-01 season, three varieties (Grafton, Icon, Millennium), which represented commercially available varieties at the time, were chosen. Grafton as the leading conventional height naked oat; Icon as the only commercially available dwarf naked oat and Millennium as a thin-husked conventional variety. These varieties were sown at five seed rates (50, 100, 200, 400 and 800 seeds m-²) in a split plot design with variety as main plots and seed rate as sub-plots each replicated four times.

In the 2001-02 season, three varieties (Grafton, Lexicon, Hendon), were chosen. Grafton as the leading conventional height naked oat; Lexicon as a popular conventional height naked oat and Hendon as a new dwarf naked oat. These varieties were sown at three seed rates (200, 400 and 600 seeds m-²). Three different seed lots of each variety from different parent seed crops were used. The experimental design was a split plot plus two way factorial with variety as main plots and seed rate and seed lot as sub-plots each replicated four times.

In the 2002-03, two varieties (Grafton, Millennium), were chosen. Grafton as the leading conventional height naked oat and Millennium as a thin-husked conventional variety. These varieties were sown at five seed rates (50, 100, 200, 400 and 600 seeds m-²) in a fully randomised two way factorial design replicated four times.

Plot sizes in all years were 2m wide by 24m long and were drilled with a Wintersteiger tractor mounted seed drill fitted with Suffolk coulters. All plots received standard rates of agrochemicals and fertilisers with an aim to maintain undisturbed and healthy crop growth.

Crop establishment was assessed pre-tillering with the number of plants counted in 10 x 1m row lengths per plot. Tiller production was assessed by fortnightly counts of ten tagged plants per plot on three seed rates in 2001 and 2002. Weekly measurements of light interception with ceptometers (Sunfleck meters) allowed canopy development to be monitored through the growing season. Crop growth was measured as both dry matter and green area index when 50% of all the main shoots reached stem extension (GS31) and at mid-anthesis (GS65). An assessment of the components of yield was made on samples taken immediately pre-harvest. Grain yield was measured using a plot combine from a harvest area of 10m by 2m. Grain specific weight was measured using a manual chondrometer, grain moisture content was calculated after oven drying at 80^{O}C for 48 hrs. Thousand-grain weight was measured using a numigral grain counter.

Year 1 (2001 harvest) results

Table 1. Autumn plant populations

Variety	Seedrate Seeds m^{-2}	Plants/m^2
Grafton	50	42.59
	100	62.22
	200	97.41
	400	185.56
	600	320.37
Grafton	Mean	141.63
Icon	50	35.93
	100	53.33
	200	95.93
	400	182.96
	600	292.96
Icon	Mean	132.22
Millennium	50	50.00
	100	93.33
	200	160.00
	400	202.22
	600	278.52
Millennium	Mean	158.44
Mean	50	42.84
	100	69.63
	200	117.78
	400	190.25
	600	297.28
Overall	Mean	144.10
CV%		**16.5**
Variety SED		**12.20**
p value		**NS**
DF		**6**
Seedrate SED		**9.74**
p value		**<0.001**
Interaction SED		**19.40**
p value		**0.016**
DF		**36**

Figure 1. Tiller production through time 2001 season mean of three varieties.

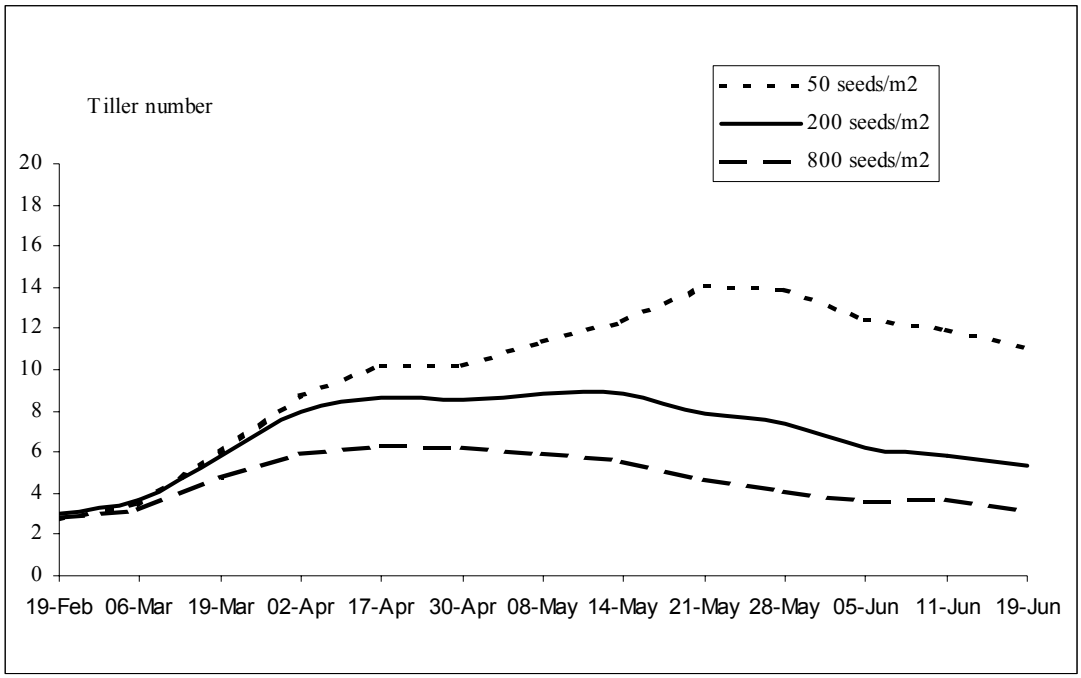

Table 2. GS31 Biomass, Canopy size

					Green area index		
Variety	Seedrate Seeds m^{-2}	Established plants m^2	Fertile shoots/m^2	Dying shoots/m^2	Leaf	Stem	Total
Grafton	50	17	212.96	3.90	0.84	0.06	0.90
	100	35	369.04	1.54	1.25	0.11	1.36
	200	107	488.30	20.77	2.20	0.16	2.36
	400	137	775.52	29.46	2.67	0.26	2.92
	600	233	817.16	62.73	3.88	0.35	4.23
Grafton	Mean	112	532.59	23.68	2.17	0.19	2.35
Icon	50	25	325.37	4.42	0.69	0.06	0.75
	100	45	608.25	9.18	1.05	0.11	1.16
	200	92	921.18	42.18	2.48	0.20	2.67
	400	195	864.22	77.77	3.11	0.26	3.37
	600	264	1354.01	180.01	4.31	0.42	4.73
Icon	Mean	114	776.08	54.33	2.19	0.19	2.38
Millennium	50	56	609.82	10.93	1.78	0.15	1.93
	100	112	642.15	17.20	2.50	0.21	2.71
	200	173	735.02	49.09	3.12	0.29	3.41
	400	161	712.22	31.70	2.95	0.25	3.20
	600	374	809.36	54.34	3.82	0.33	4.15
Millennium	Mean	160	701.71	32.65	2.83	0.25	3.08
Mean	50	32.8	382.72	6.42	1.10	0.09	1.19
	100	63.8	539.81	9.31	1.60	0.14	1.74
	200	124.2	714.83	37.35	2.60	0.22	2.81
	400	164.3	783.99	46.31	2.91	0.25	3.16
	600	290.1	993.51	99.03	4.00	0.36	4.37
Overall	Mean	128	667.72	36.49	2.40	0.21	2.61
CV%		**7.7**	**9.9**	**43.0**	**7.3**	**5.4**	**6.7**
	Variety SED	**8.51**	**54.80**	**13.78**	**0.14**	**0.01**	**0.14**
	p value	**0.003**	**0.017**	**0.103**	**0.027**	**0.014**	**0.021**
	DF	**4**	**4**	**4**	**4**	**4**	**4**
	Seedrate SED	**13.94**	**100.50**	**9.56**	**0.28**	**0.02**	**0.30**
	p value	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
	Interaction SED	**23.22**	**165.10**	**20.23**	**0.46**	**0.04**	**0.49**
	p value	**0.009**	**0.118**	**<0.001**	**NS**	**0.07**	**NS**
	DF	**22**	**22**	**22**	**22**	**22**	**22**

Table 3. GS31 Biomass, Crop dry matter t/ha

Variety	Seedrate Seeds m^{-2}	Green Leaf	Green Stem	Total
Grafton	50	0.45	0.22	0.70
	100	0.62	0.36	0.99
	200	1.20	0.67	1.98
	400	1.44	0.97	2.55
	600	2.23	1.72	4.30
Grafton	Mean	1.19	0.79	2.10
Icon	50	0.38	0.17	0.57
	100	0.55	0.33	0.95
	200	1.32	0.72	2.24
	400	1.76	0.99	3.05
	600	2.59	1.77	5.09
Icon	Mean	1.23	0.73	2.18
Millennium	50	1.15	0.76	1.96
	100	1.74	1.03	2.83
	200	2.04	1.29	3.56
	400	1.97	1.25	3.37
	600	2.51	1.71	4.56
Millennium	Mean	1.88	1.21	3.26
Mean	50	0.66	0.38	1.08
	100	0.97	0.58	1.59
	200	1.52	0.89	2.59
	400	1.73	1.07	2.99
	600	2.44	1.73	4.65
Overall	Mean	1.44	0.91	2.52
CV%		6.2	7.5	6.1
	Variety SED	0.07	0.06	0.13
	p value	0.002	0.004	0.002
	DF	4	4	4
	Seedrate SED	0.15	0.10	0.25
	p value	<0.001	<0.001	<0.001
	Interaction SED	0.25	0.17	0.41
	p value	0.111	NS	0.047
	DF	22	22	22

Table 4. GS65 Biomass, Canopy size

			Green Area Index			
Variety	Seedrate Seeds m^{-2}	Fertile shoots/m^2	Leaf	Stem	Ear	Total
Grafton	50	164.40	1.77	0.96	0.50	3.23
	100	170.07	2.29	0.73	0.60	3.62
	200	199.95	2.23	0.79	0.61	3.62
	400	326.40	2.49	1.01	0.79	4.29
	600	461.88	2.43	1.14	0.72	4.29
Grafton	Mean	264.54	2.24	0.93	0.64	3.81
Icon	50	281.44	2.89	0.68	0.95	4.53
	100	244.98	2.40	0.57	0.82	3.79
	200	333.08	2.96	0.72	0.82	4.50
	400	418.43	2.63	0.78	0.87	4.27
	600	694.66	4.02	1.11	1.22	6.34
Icon	Mean	373.08	2.91	0.75	0.92	4.57
Millennium	50	246.42	2.53	0.86	0.49	3.87
	100	323.73	2.38	0.88	0.48	3.74
	200	353.37	2.08	0.94	0.48	3.51
	400	477.21	3.11	1.18	0.64	4.93
	600	690.77	2.87	1.34	0.60	4.81
Millennium	Mean	422.94	2.63	1.05	0.54	4.22
Mean	50	230.75	2.40	0.83	0.65	3.88
	100	246.26	2.36	0.73	0.63	3.72
	200	295.47	2.42	0.82	0.64	3.88
	400	407.35	2.74	0.99	0.77	4.50
	600	615.77	3.11	1.20	0.84	5.15
Overall	Mean	351.45	2.58	0.91	0.70	4.19
CV%		**20.1**	**25.0**	**21.3**	**19.7**	**20.5**
	Variety SED	**35.5**	**0.319**	**0.074**	**0.097**	**0.464**
	p value	**0.025**	**NS**	**0.065**	**0.028**	**NS**
	DF	**4**	**4**	**4**	**4**	**4**
	Seedrate SED	**33.9**	**0.308**	**0.092**	**0.066**	**0.409**
	p value	**<0.001**	**0.071**	**<0.001**	**0.004**	**0.005**
	Interaction SED	**63.4**	**0.574**	**0.160**	**0.141**	**0.785**
	p value	**NS**	**NS**	**NS**	**NS**	**NS**
	DF	**22**	**22**	**22**	**22**	**22**

Table 5. GS65 Biomass, Crop dry matter t/ha

Variety	Seedrate Seeds m^{-2}	Green Leaf	Green Stem	Green Ear	Total
Grafton	50	1.26	4.87	2.28	8.49
	100	1.15	4.90	2.09	8.25
	200	1.23	5.54	2.47	9.25
	400	1.19	6.09	2.79	10.22
	600	1.18	6.28	2.99	10.61
Grafton	Mean	1.20	5.54	2.52	9.36
Icon	50	1.33	4.25	3.37	9.03
	100	1.18	4.37	3.34	9.07
	200	1.30	4.81	3.32	9.60
	400	1.17	4.79	3.77	9.91
	600	1.64	6.73	5.11	13.83
Icon	Mean	1.30	4.87	3.69	10.04
Millennium	50	1.43	5.13	2.36	9.09
	100	1.31	5.91	2.80	10.18
	200	1.16	5.91	2.74	9.95
	400	1.51	6.73	3.06	11.47
	600	1.35	7.13	3.71	12.34
Millennium	Mean	1.37	6.18	2.95	10.65
Mean	50	1.34	4.75	2.67	8.87
	100	1.21	5.06	2.74	9.17
	200	1.23	5.42	2.84	9.60
	400	1.29	5.87	3.20	10.53
	600	1.39	6.72	3.94	12.26
Overall	Mean	1.29	5.53	3.04	10.00
CV%		**19.3**	**18.1**	**18.7**	**17.7**
	Variety SED	**0.122**	**0.398**	**0.321**	**0.851**
	p value	**NS**	**NS**	**0.036**	**NS**
	DF	**4**	**4**	**4**	**4**
	Seedrate SED	**0.118**	**0.474**	**0.272**	**0.843**
	p value	**NS**	**0.002**	**<0.001**	**0.002**
	Interaction SED	**0.219**	**0.836**	**0.530**	**1.559**
	p value	**NS**	**NS**	**NS**	**NS**
	DF	**22**	**22**	**22**	**22**

Table 6. Pre-harvest Biomass, Crop dry matter t/ha

Variety	Seedrate Seeds m^{-2}	Straw	Grain	Chaff	Total
Grafton	50	3.23	3.06	1.51	7.80
	100	4.33	4.23	1.89	10.45
	200	3.89	3.80	1.70	9.38
	400	5.49	5.72	2.36	13.57
	600	4.78	5.10	1.84	11.73
Grafton	Mean	4.35	4.38	1.86	10.59
Icon	50	2.56	3.46	2.35	8.37
	100	3.14	3.81	2.38	9.33
	200	2.88	3.59	2.23	8.70
	400	3.83	4.88	2.48	11.19
	600	3.42	4.47	2.21	10.10
Icon	Mean	3.15	4.01	2.34	9.50
Millennium	50	4.61	5.32	1.24	11.18
	100	4.08	5.63	1.10	10.81
	200	3.98	5.55	1.11	10.64
	400	4.96	6.54	1.17	12.67
	600	4.63	5.74	1.06	11.43
Millennium	Mean	4.48	5.77	1.14	11.40
Mean	50	3.47	3.95	1.70	9.12
	100	3.85	4.56	1.79	10.20
	200	3.58	4.31	1.68	9.57
	400	4.76	5.71	2.00	12.48
	600	4.28	5.11	1.70	11.09
Overall	Mean	4.00	4.71	1.78	10.50
CV%		**3.0**	**2.5**	**4.7**	**2.6**
Variety SED		**0.10**	**0.10**	**0.07**	**0.23**
p value		**<0.001**	**<0.001**	**<0.001**	**0.005**
DF		**4**	**4**	**4**	**4**
Seedrate SED		**0.28**	**0.40**	**0.14**	**0.75**
p value		**<0.001**	**0.002**	**0.147**	**0.001**
Interaction SED		**0.44**	**0.63**	**0.22**	**1.18**
p value		**NS**	**NS**	**NS**	**NS**
DF		**22**	**22**	**22**	**22**

Table 7. Pre-harvest Biomass, yield components

Variety	Seedrate Seeds m^{-2}	Harvest Index	Thousand grain weight g @ 85%	Grain weight (g)/ear	Grain number /ear	Ear number /m^2
Grafton	50	38.66	35.31	2.11	68.78	144.23
	100	40.17	32.19	2.10	75.72	201.42
	200	39.88	30.34	1.75	66.91	212.79
	400	42.19	28.73	1.43	56.91	403.59
	600	43.53	28.53	1.19	48.33	432.35
Grafton	Mean	40.89	31.02	1.71	63.33	278.88
Icon	50	40.61	35.28	1.94	68.90	182.00
	100	40.64	32.47	1.78	63.23	216.32
	200	41.10	31.92	1.49	53.94	238.53
	400	43.65	30.93	1.26	46.72	394.43
	600	44.31	29.28	1.08	42.53	420.35
Icon	Mean	41.90	32.17	1.54	55.96	281.04
Millennium	50	47.66	48.00	2.24	53.57	262.98
	100	52.11	49.02	2.02	47.26	284.12
	200	52.15	48.21	1.53	36.63	361.37
	400	51.60	47.66	1.41	34.03	464.48
	600	50.39	42.17	1.04	28.70	562.60
Millennium	Mean	50.68	46.93	1.66	40.28	388.95
Mean	50	42.31	39.53	2.09	63.75	196.40
	100	44.30	37.89	1.97	62.07	233.95
	200	44.38	36.82	1.59	52.49	270.90
	400	45.81	35.77	1.37	45.89	420.83
	600	46.08	33.33	1.10	39.85	471.76
Overall	Mean	44.41	36.57	1.64	53.43	315.42
CV%		**1.8**	**3.5**	**7.6**	**8.3**	**4.3**
Variety SED		**0.67**	**1.05**	**0.10**	**3.58**	**11.10**
p value		**<0.001**	**<0.001**	**NS**	**0.007**	**0.001**
DF		**4**	**4**	**4**	**4**	**4**
Seedrate SED		**1.42**	**1.66**	**0.18**	**6.70**	**32.80**
p value		**0.09**	**0.009**	**<0.001**	**0.009**	**<0.001**
Interaction SED		**2.29**	**2.78**	**0.30**	**10.98**	**52.00**
p value		**NS**	**NS**	**NS**	**NS**	**NS**
DF		**22**	**22**	**22**	**22**	**22**

Table 8. Harvest data

Variety	Seedrate Seeds m^{-2}	Grain yield t/ha	Specific weight kg/hl
Grafton	50	2.85	65.88
	100	3.63	66.11
	200	4.23	65.53
	400	5.28	64.97
	600	5.65	63.53
Grafton	Mean	4.33	65.20
Icon	50	3.54	65.22
	100	4.69	64.84
	200	5.02	65.61
	400	5.91	65.74
	600	5.63	65.53
Icon	Mean	4.92	65.38
Millennium	50	5.37	52.19
	100	6.52	52.56
	200	6.54	52.41
	400	7.28	52.07
	600	7.55	51.22
Millennium	Mean	6.66	52.08
Mean	50	3.92	61.10
	100	4.95	61.17
	200	5.26	61.19
	400	6.16	60.93
	600	6.28	60.10
Overall	Mean	5.29	60.96
CV%		**3.8**	**1.4**
Variety SED		**0.14**	**0.59**
p value		**<0.001**	**<0.001**
DF		**6**	**6**
Seedrate SED		**0.18**	**0.47**
p value		**<0.001**	**0.007**
Interaction SED		**0.31**	**0.93**
p value		**NS**	**NS**
DF		**36**	**36**

Year 2 (2002 harvest) results

Table 9. Autumn plant populations

		Seed Lot		
Variety	Seedrate Seeds m^{-2}	1	2	3
Grafton	200	111.11	120.49	103.21
	400	193.09	199.51	213.83
	600	230.12	291.36	239.01
Grafton	Mean	178.11	203.79	185.35
Hendon	200	156.05	167.90	174.81
	400	290.37	283.46	304.69
	600	358.52	396.54	378.27
Hendon	Mean	268.31	282.63	285.93
Lexicon	200	109.89	135.31	109.89
	400	142.48	226.18	203.22
	600	225.68	295.31	307.67
Lexicon	Mean	168.25	217.78	205.93
Mean	200	125.35	141.23	129.27
	400	208.31	236.05	240.65
	600	271.44	327.74	307.98
Overall	Mean	207.82	235.38	228.21
	CV%		**8.8**	
	Variety SED		**10.79**	
	p value		**0.002**	
	DF		**4**	
	Seedrate SED		**5.29**	
	p value		**<0.001**	
	Seedlot SED		**5.29**	
	p value		**<0.001**	
	Variety x Seedrate SED		**8.58**	
	p value		**<0.001**	
	Variety x Seedlot SED		**13.13**	
	p value		**0.004**	
	Seedrate x Seedlot SED		**9.16**	
	p value		**0.013**	
	Variety x Seedrate x Seedlot SED		**18.45**	
	p value		**0.030**	
	DF		**42**	

Figure 2. Tiller production through time 2002 season mean of three varieties

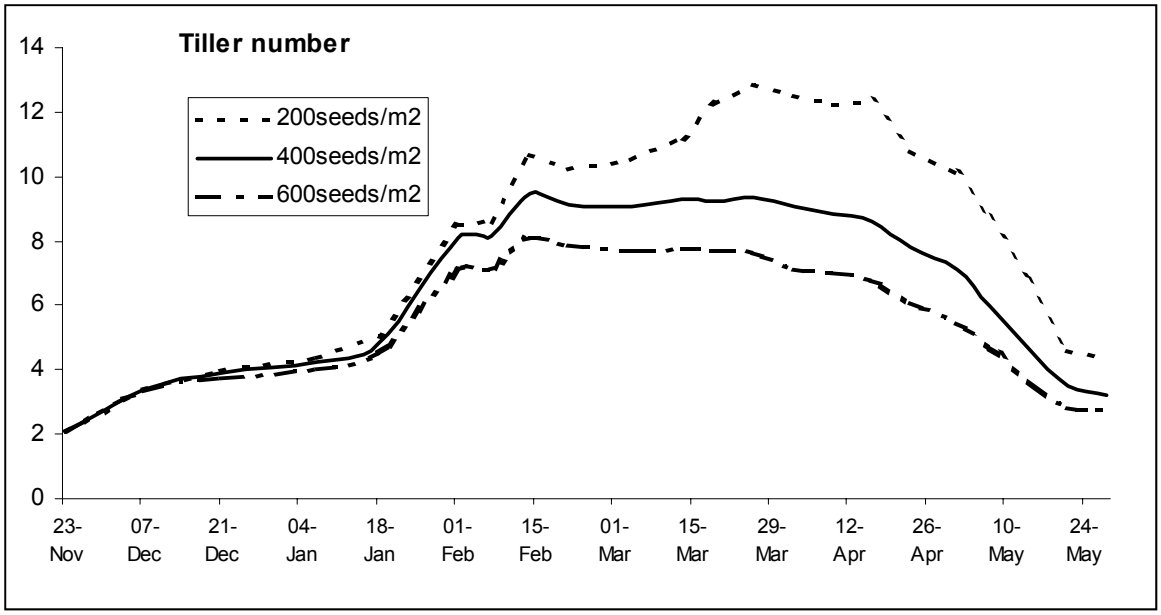

Figure 3. Percentage Photosynthetic Active Radiation absorbed by the crop mean of three varieties.

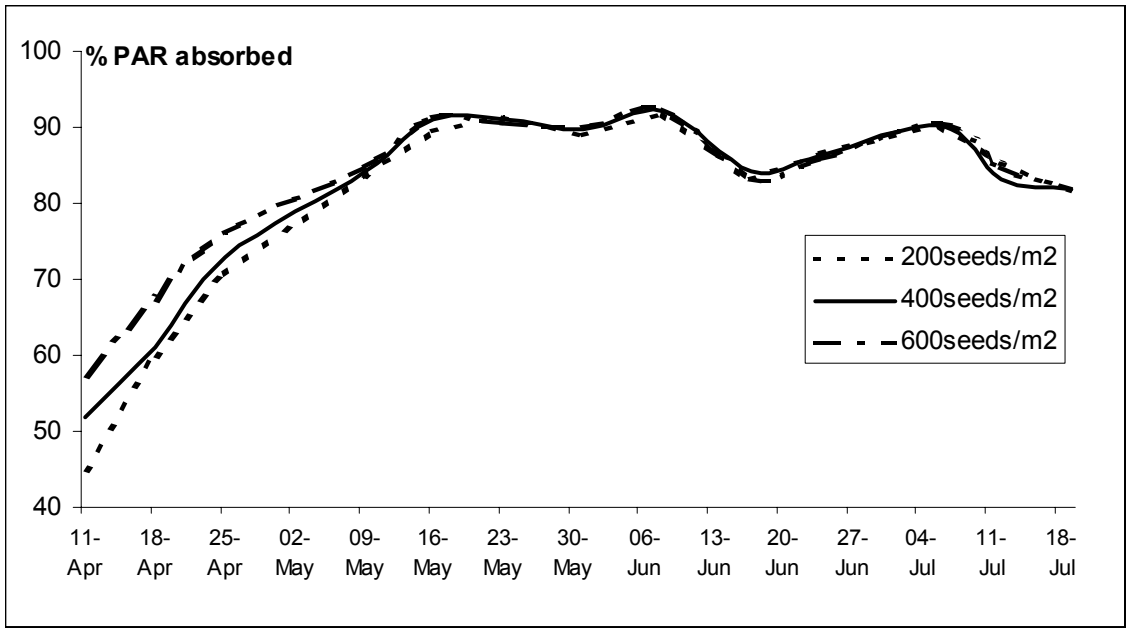

Table 10. GS31 Biomass, Canopy size

					Green area index		
Variety	Seedrate Seeds m^{-2}	Established plants m^2	Fertile shoots/m^2	Dying shoots/m^2	Leaf	Stem	Total
Grafton	200	99.59	741.50	105.94	5.59	0.43	6.02
	400	138.68	644.62	205.24	6.80	0.48	7.28
	600	165.43	720.13	128.92	6.71	0.43	7.14
Grafton	Mean	134.57	702.08	146.70	6.37	0.45	6.81
Hendon	200	102.47	876.06	45.26	5.18	0.33	5.51
	400	183.13	851.99	85.79	5.40	0.36	5.77
	600	197.53	903.29	244.43	5.26	0.45	5.71
Hendon	Mean	161.04	877.12	125.16	5.28	0.38	5.66
Lexicon	200	126.34	923.68	259.86	5.31	0.43	5.75
	400	143.21	1007.06	225.34	5.83	0.45	6.28
	600	158.02	881.42	255.83	5.39	0.40	5.79
Lexicon	Mean	142.52	937.38	247.01	5.51	0.43	5.94
Mean	200	109.47	847.08	137.02	5.36	0.40	5.76
	400	155.01	834.56	172.13	6.01	0.43	6.44
	600	173.66	834.94	209.72	5.79	0.43	6.21
Overall	Mean	146.04	838.86	172.96	5.72	0.42	6.14
CV%		**18.0**	**18.0**	**66.1**	**16.4**	**19.1**	**11.7**
	Variety SED	**10.86**	**73.0**	**46.7**	**0.653**	**0.157**	**0.388**
	p value	**NS**	**0.069**	**NS**	**NS**	**NS**	**NS**
	DF	**4**	**4**	**4**	**4**	**4**	**4**
	Seedrate SED	**9.74**	**71.2**	**40.9**	**0.443**	**0.136**	**0.250**
	p value	**<0.001**	**NS**	**NS**	**NS**	**NS**	**0.041**
Variety x Seedrate SED		**17.54**	**124.4**	**87.8**	**0.905**	**0.247**	**0.526**
	p value	**NS**	**NS**	**NS**	**NS**	**NS**	**0.048**
	DF	**12**	**12**	**12**	**12**	**12**	**12**

Table 11. GS31 Biomass, Crop dry matter t/ha

Variety	Seedrate Seeds m^{-2}	Green Leaf	Green Stem	Dead leaf	Dead & Dying shoots	Total
Grafton	200	2.37	1.49	0.18	0.07	4.12
	400	2.82	1.84	0.85	0.17	5.68
	600	2.82	1.59	0.21	0.08	4.70
Grafton	Mean	2.67	1.64	0.41	0.11	4.83
Hendon	200	2.59	1.18	0.10	0.02	3.88
	400	2.80	1.33	0.16	0.04	4.32
	600	2.88	1.79	0.29	0.15	5.10
Hendon	Mean	2.75	1.43	0.18	0.07	4.44
Lexicon	200	2.55	1.52	0.17	0.18	4.43
	400	2.69	1.46	0.20	0.14	4.48
	600	2.63	1.34	0.16	0.14	4.27
Lexicon	Mean	2.62	1.44	0.18	0.15	4.39
Mean	200	2.50	1.40	0.15	0.09	4.14
	400	2.77	1.54	0.40	0.11	4.83
	600	2.78	1.57	0.22	0.12	4.69
Overall	Mean	2.68	1.50	0.26	0.11	4.55
CV%		**13.3**	**19.1**	**130.9**	**58.4**	**11.7**
	Variety SED	**0.210**	**0.156**	**0.169**	**0.051**	**0.388**
	p value	**NS**	**NS**	**NS**	**NS**	**NS**
	DF	**4**	**4**	**4**	**4**	**4**
	Seedrate SED	**0.169**	**0.136**	**0.159**	**0.030**	**0.250**
	p value	**NS**	**NS**	**NS**	**NS**	**0.041**
Variety x Seedrate SED		**0.318**	**0.247**	**0.282**	**0.066**	**0.526**
	p value	**NS**	**NS**	**NS**	**0.087**	**0.048**
	DF	**12**	**12**	**12**	**12**	**12**

Table 12. GS65 Biomass, Canopy size

				Green Area Index			
Variety	Seedrate Seeds m^{-2}	Fertile shoots/m^2	Dying shoots/m^2	Leaf	Stem	Ear	Total
Grafton	200	252.34	69.30	5.41	2.07	0.89	8.37
	400	348.90	33.15	5.50	2.18	0.90	8.59
	600	410.54	37.77	5.62	2.22	0.92	8.76
Grafton	Mean	337.26	46.74	5.51	2.16	0.91	8.57
Hendon	200	324.65	45.28	5.06	1.34	1.03	7.43
	400	437.86	68.68	4.68	1.55	1.19	7.42
	600	444.93	43.59	4.74	1.50	1.04	7.28
Hendon	Mean	402.48	52.52	4.83	1.46	1.09	7.38
Lexicon	200	286.83	63.62	4.90	1.98	0.84	7.72
	400	415.69	178.76	5.31	2.51	1.04	8.85
	600	419.91	166.92	4.55	2.33	0.92	7.79
Lexicon	Mean	374.14	136.43	4.92	2.27	0.93	8.12
Mean	200	287.94	59.40	5.12	1.80	0.92	7.84
	400	400.82	93.53	5.16	2.08	1.04	8.29
	600	425.12	82.76	4.97	2.01	0.96	7.94
Overall	Mean	371.29	78.56	5.08	1.96	0.97	8.02
	CV%	**14.2**	**46.5**	**9.7**	**11.2**	**8.7**	**9.2**
	Variety SED	**28.5**	**21.55**	**0.555**	**0.186**	**0.037**	**0.738**
	p value	**NS**	**0.024**	**NS**	**0.023**	**0.015**	**NS**
	DF	**4**	**4**	**4**	**4**	**4**	**4**
	Seedrate SED	**24.9**	**17.22**	**0.232**	**0.104**	**0.040**	**0.348**
	p value	**<0.001**	**NS**	**NS**	**0.045**	**0.028**	**NS**
	Variety x Seedrate SED	**45.3**	**32.51**	**0.645**	**0.237**	**0.068**	**0.887**
	p value	**NS**	**0.025**	**NS**	**NS**	**NS**	**NS**
	DF	**12**	**12**	**12**	**12**	**12**	**12**

Table 13. GS65 Biomass, Crop dry matter t/ha

Variety	Seedrate Seeds m^{-2}	Green Leaf	Green Stem	Green Ear	Total
Grafton	200	2.08	9.62	3.79	16.13
	400	2.15	9.49	4.06	16.20
	600	2.03	8.75	4.31	15.67
Grafton	Mean	2.08	9.29	4.05	16.00
Hendon	200	2.23	7.68	4.20	14.52
	400	2.08	8.17	4.99	15.85
	600	2.01	7.61	4.95	15.13
Hendon	Mean	2.11	7.82	4.71	15.17
Lexicon	200	2.03	9.03	3.41	14.99
	400	2.20	10.11	4.09	17.19
	600	1.91	9.08	3.75	15.41
Lexicon	Mean	2.04	9.41	3.75	15.86
Mean	200	2.11	8.78	3.80	15.21
	400	2.14	9.26	4.38	16.41
	600	1.98	8.48	4.34	15.40
Overall	Mean	2.08	8.84	4.17	15.68
	CV%	**7.8**	**6.8**	**8.3**	**6.4**
	Variety SED	**0.163**	**0.405**	**0.156**	**0.679**
	p value	**NS**	**0.030**	**0.009**	**NS**
	DF	**4**	**4**	**4**	**4**
	Seedrate SED	**0.077**	**0.284**	**0.163**	**0.472**
	p value	**NS**	**0.052**	**0.006**	**0.055**
	Variety x Seedrate SED	**0.196**	**0.570**	**0.278**	**0.953**
	p value	**NS**	**NS**	**NS**	**NS**
	DF	**12**	**12**	**12**	**12**

Table 14. Yield t/ha @ 85%

		Seed Lot		
Variety	Seedrate Seeds m^{-2}	1	2	3
Grafton	200	6.23	6.51	6.16
	400	6.63	6.76	6.55
	600	6.92	6.84	6.76
Grafton	Mean	6.59	6.70	6.49
Hendon	200	6.90	7.24	7.35
	400	7.51	7.66	7.56
	600	7.40	7.16	7.57
Hendon	Mean	7.27	7.35	7.49
Lexicon	200	6.14	6.22	6.11
	400	6.27	6.93	6.60
	600	6.47	6.85	6.69
Lexicon	Mean	6.29	6.67	6.44
Mean	200	6.42	6.66	6.54
	400	6.80	7.12	6.90
	600	6.93	6.95	7.01
Overall	Mean	6.72	6.91	6.82
	CV%		**4.0**	
	Variety SED		**0.107**	
	p value		**0.002**	
	DF		**4**	
	Seedrate SED		**0.074**	
	p value		**<0.001**	
	Seedlot SED		**0.066**	
	p value		**0.042**	
	Variety x Seedrate SED		**0.149**	
	p value		**NS**	
	Variety x Seedlot SED		**0.142**	
	p value		**NS**	
	Seedrate x Seedlot SED		**0.123**	
	p value		**NS**	
	Variety x Seedrate x Seedlot SED		**0.230**	
	p value		**NS**	
	DF		**23**	

Table 15. Specific Weight kg/hl

		Seed Lot		
Variety	Seedrate Seeds m^{-2}	1	2	3
Grafton	200	67.95	67.98	68.28
	400	68.35	68.03	68.01
	600	67.91	67.93	67.42
Grafton	Mean	68.07	67.98	67.90
Hendon	200	65.96	65.49	65.75
	400	65.25	65.06	65.62
	600	65.42	65.00	65.39
Hendon	Mean	65.54	65.19	65.59
Lexicon	200	65.87	66.23	66.38
	400	66.25	67.36	66.09
	600	66.66	65.92	66.22
Lexicon	Mean	66.26	66.50	66.23
Mean	200	66.59	66.56	66.80
	400	66.62	66.82	66.57
	600	66.66	66.28	66.34
Overall	Mean	66.62	66.56	66.57
	CV%		**1.0**	
	Variety SED		**0.279**	
	p value		**0.002**	
	DF		**4**	
	Seedrate SED		**0.233**	
	p value		**NS**	
	Seedlot SED		**0.186**	
	p value		**NS**	
	Variety x Seedrate SED		**0.431**	
	p value		**NS**	
	Variety x Seedlot SED		**0.383**	
	p value		**NS**	
	Seedrate x Seedlot SED		**0.345**	
	p value		**NS**	
	Variety x Seedrate x Seedlot SED		**0.613**	
	p value		**NS**	
	DF		**24**	

Table 16. Thousand grain weight g

		Seed Lot		
Variety	Seedrate Seeds m^{-2}	1	2	3
Grafton	200	30.97	31.41	30.96
	400	30.42	33.77	30.21
	600	29.96	30.82	30.13
Grafton	Mean	30.45	32.00	30.43
Hendon	200	24.94	26.95	26.86
	400	27.12	25.99	26.25
	600	26.03	26.28	26.64
Hendon	Mean	26.03	26.41	26.58
Lexicon	200	28.81	27.91	28.20
	400	25.74	28.04	27.56
	600	28.01	28.28	27.46
Lexicon	Mean	27.52	28.08	27.74
Mean	200	28.24	28.76	28.67
	400	27.76	29.27	28.01
	600	28.00	28.46	28.08
Overall	Mean	28.00	28.83	28.25
	CV%		**7.4**	
	Variety SED		**0.255**	
	p value		**<0.001**	
	DF		**4**	
	Seedrate SED		**0.523**	
	p value		**NS**	
	Seedlot SED		**0.315**	
	p value		**0.058**	
	Variety x Seedrate SED		**0.783**	
	p value		**NS**	
	Variety x Seedlot SED		**0.513**	
	p value		**NS**	
	Seedrate x Seedlot SED		**0.834**	
	p value		**NS**	
	Variety x Seedrate x Seedlot SED		**1.450**	
	p value		**NS**	
	DF		**24**	

Table 17. Autumn plant populations

Variety	Seedrate Seeds m^{-2}	Plants/m^2
Grafton	50	47.78
	100	81.48
	200	143.33
	400	283.33
	600	360.00
Grafton	Mean	183.19
Millennium	50	62.59
	100	109.63
	200	188.15
	400	325.18
	600	468.15
Millennium	Mean	230.74
Mean	50	55.19
	100	95.56
	200	165.74
	400	304.26
	600	414.07
Overall	Mean	206.96
CV%		**9.7**
Variety SED		**6.36**
p value		**<0.001**
Seedrate SED		**10.06**
p value		**<0.001**
Interaction SED		**14.23**
p value		**<0.001**
DF		**27**

Figure 4. Percentage Photosynthetic Active Radiation absorbed by the crop mean of two varieties.

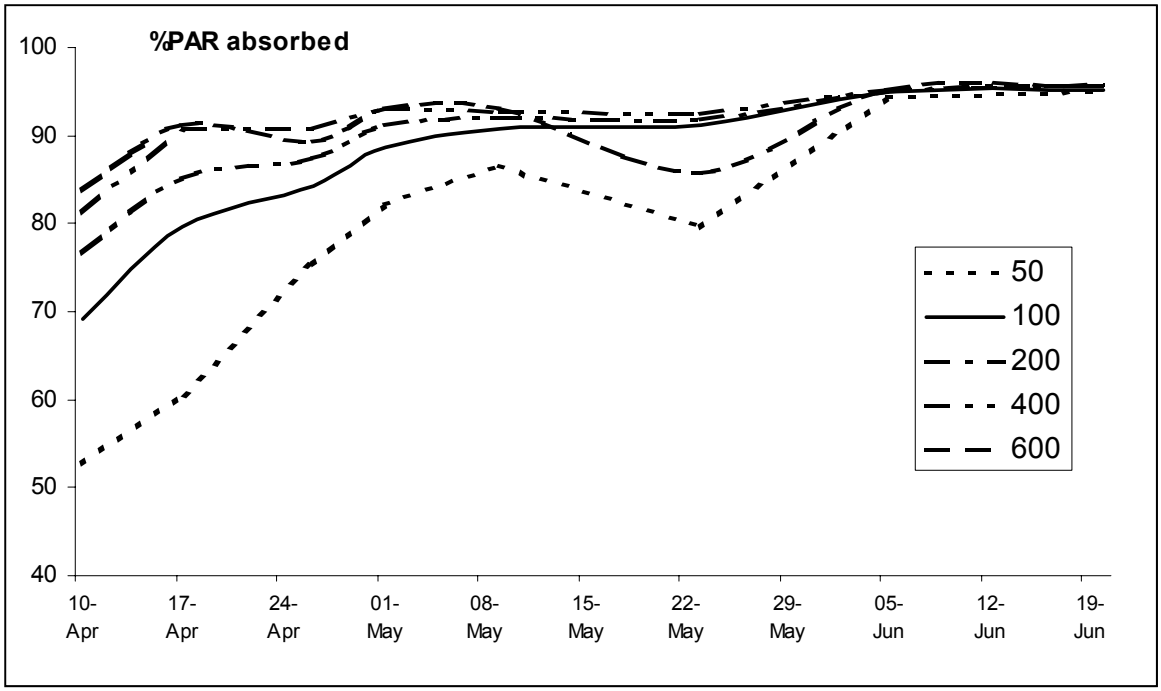

Table 18. Pre-harvest Biomass, Crop dry matter t/ha

Variety	Seedrate Seeds m^{-2}	Straw	Grain	Chaff	Total
Grafton	50	7.84	5.84	1.91	15.60
	100	9.57	5.78	2.02	17.37
	200	8.50	5.10	2.12	15.72
	400	8.13	4.91	1.46	14.49
	600	8.12	5.41	1.46	14.99
Grafton	Mean	8.43	5.41	1.79	15.63
Millennium	50	9.74	5.38	4.14	19.27
	100	7.36	6.44	2.08	15.88
	200	6.30	4.47	1.23	11.99
	400	8.13	4.16	1.35	13.64
	600	7.25	4.41	1.44	13.10
Millennium	Mean	7.76	4.97	2.05	14.78
Mean	50	8.79	5.61	3.03	17.43
	100	8.47	6.11	2.05	16.63
	200	7.40	4.78	1.68	13.86
	400	8.13	4.53	1.40	14.07
	600	7.68	4.91	1.45	14.05
Overall	Mean	8.09	5.19	1.92	15.21
	CV%	**17.7**	**29.5**	**39.0**	**18.4**
	Variety SED	**0.452**	**0.484**	**0.237**	**0.887**
	p value	**NS**	**NS**	**NS**	**NS**
	Seedrate SED	**0.715**	**0.765**	**0.374**	**1.402**
	p value	**NS**	**NS**	**<0.001**	**0.040**
	Interaction SED	**1.011**	**1.082**	**0.529**	**1.983**
	p value	**0.041**	**NS**	**0.004**	**NS**
	DF	**27**	**27**	**27**	**27**

Table 19. Pre-harvest Biomass, yield components

Variety	Seedrate Seeds m^{-2}	Harvest Index	Thousand grain weight g @ 85%	Grain weight (g)/ear	Grain number /ear	Ear number $/m^2$
Grafton	50	37.45	28.62	2.57	104.26	229.21
	100	33.34	30.28	1.54	59.42	416.91
	200	32.41	28.10	1.57	64.08	328.33
	400	33.95	28.24	1.57	64.31	320.07
	600	36.05	30.18	1.41	54.77	392.21
Grafton	Mean	34.64	29.08	1.73	69.37	337.35
Millennium	50	27.66	31.21	1.36	49.58	393.74
	100	40.49	34.92	1.48	49.20	430.27
	200	36.89	33.34	1.09	37.20	412.93
	400	29.66	29.44	0.89	33.15	477.19
	600	32.16	29.58	0.96	37.99	520.06
Millennium	Mean	33.37	31.70	1.15	41.42	446.84
Mean	50	32.56	29.91	1.97	76.92	311.48
	100	36.91	32.60	1.51	54.31	423.59
	200	34.65	30.72	1.33	50.64	370.63
	400	31.81	28.84	1.23	48.73	398.63
	600	34.11	29.88	1.19	46.38	456.14
Overall	Mean	34.01	30.39	1.44	55.40	392.09
CV%		**19.7**	**15.1**	**29.8**	**29.5**	**20.9**
Variety SED		**2.12**	**1.453**	**0.136**	**5.18**	**25.9**
p value		**NS**	**NS**	**<0.001**	**<0.001**	**<0.001**
Seedrate SED		**3.35**	**2.298**	**0.215**	**8.18**	**40.9**
p value		**NS**	**NS**	**0.008**	**0.006**	**0.018**
Interaction SED		**4.74**	**3.250**	**0.304**	**11.57**	**57.9**
p value		**NS**	**NS**	**NS**	**NS**	**NS**
DF		**27**	**27**	**27**	**27**	**27**

Table 20. Harvest data

Variety	Seedrate Seeds m^{-2}	Grain yield t/ha	Specific weight kg/hl	Thousand grain weight g
Grafton	50	5.91	62.49	29.56
	100	6.69	63.68	29.77
	200	6.70	64.84	27.74
	400	7.14	64.79	27.88
	600	6.09	64.44	26.87
Grafton	Mean	6.47	64.05	28.36
Millennium	50	8.45	52.15	39.76
	100	8.66	52.01	38.78
	200	8.28	49.24	37.88
	400	8.07	50.17	38.90
	600	7.61	49.06	37.68
Millennium	Mean	8.21	50.53	38.60
Mean	50	7.18	57.32	34.66
	100	7.68	57.85	34.28
	200	7.49	57.04	32.81
	400	7.61	57.48	33.39
	600	6.85	56.75	32.28
Overall	Mean	7.37	57.29	33.48
CV%		**6.2**	**3.0**	**5.8**
Variety SED		**0.145**	**0.551**	**0.610**
p value		**<0.001**	**<0.001**	**<0.001**
Seedrate SED		**0.229**	**0.871**	**0.964**
p value		**0.007**	**NS**	**NS**
Interaction SED		**0.324**	**1.232**	**1.363**
p value		**0.022**	**0.016**	**NS**
DF		**26**	**27**	**27**

Table 21. Whole plot lodging assessments

		Lodging assessments %		
Variety	Seedrate Seeds m^{-2}	20th June	17th July	29th July
Grafton	50	0.00	0.00	0.00
	100	0.00	0.00	10.00
	200	0.00	1.25	30.00
	400	0.00	1.25	70.00
	600	0.00	13.25	83.75
Grafton	Mean	0.00	3.15	38.75
Millennium	50	0.00	2.00	10.00
	100	0.00	20.75	35.00
	200	18.75	66.25	66.25
	400	38.75	48.75	66.25
	600	42.50	77.50	71.25
Millennium	Mean	20.00	43.05	49.75
Mean	50	0.00	1.00	5.00
	100	0.00	10.38	22.50
	200	9.38	33.75	48.13
	400	19.38	25.00	68.13
	600	21.25	45.38	77.50
Overall	Mean	10.00	23.10	44.25
CV%		**71.7**	**59.9**	**35.7**
Variety SED		**2.27**	**4.38**	**5.00**
p value		**<0.001**	**<0.001**	**0.037**
Seedrate SED		**3.58**	**6.92**	**7.91**
p value		**<0.001**	**<0.001**	**<0.001**
Interaction SED		**5.07**	**9.79**	**11.18**
p value		**<0.001**	**<0.001**	**0.028**
DF		**27**	**27**	**27**

APPENDIX 2

Variety evaluation experiments

Materials and Methods

Experiments were carried out at ADAS Rosemaund, Herefordshire (52.1^{O}N, 2.5^{O}W) in each of three years 2001 to 2003. A range of varieties were sown at a standard seed rate (400 seeds m^{-2}). The list of varieties tested in each year can be seen in the following table.

Variety	2001	2002	2003
Ayr			✓
Birnam	✓		
Buffalo		✓	✓
Dalguise		✓	✓
Expression	✓	✓	✓
Gerald	✓	✓	✓
Grafton	✓	✓	✓
Harpoon	✓	✓	
Hendon	✓	✓	✓
Icon	✓		
Image	✓		
Jalna	✓	✓	✓
Kingfisher	✓	✓	✓
Krypton	✓	✓	
Lexicon	✓	✓	
Millennium	✓	✓	✓
Viscount	✓		
91-229Cn234 (Chris – high oil)	✓	✓	✓
91-229Cn253 (Fatso – high oil	✓		
93-76Cn1/1	✓		
94-116Cn4/1 (New husked dwarf)		✓	✓
95-205Acn1/2 (Large grained short naked)		✓	
95-56Acn3 (MM/Jalna)	✓	✓	
96-140Cn1 (New high oil)		✓	
95-240Cn 3/1/1/1			✓
95-27 Cn5/1			✓
95-75 Cn5/1			✓

The experimental design was fully randomised block design with four replicates.

Plot sizes in all years were 2m wide by 24m long and were drilled with a Wintersteiger tractor mounted seed drill fitted with Suffolk coulters. All plots received standard rates of agrochemicals and fertilisers with an aim to maintain undisturbed and healthy crop growth.

Crop establishment was assessed pre-tillering with the number of plants counted in 10 x 1m row lengths per plot. An assessment of the components of yield was made on samples taken immediately pre-harvest. Grain yield was measured using a plot combine from a harvest area of 10m by 2m. Grain specific weight was measured using a manual chondrometer, grain moisture content was calculated after oven drying at 80^{O}C for 48 hrs. Thousand-grain weight was measured using a numigral grain counter.

Year 1 (2001 harvest) results

Table 22. Autumn plant populations

Variety	Plants/m^2
Birnam	157.4
Expression	200.0
Gerald	204.8
Grafton	182.2
Harpoon	181.9
Hendon	211.1
Icon	150.0
Image	*
Jalna	136.3
Kingfisher	221.5
Krypton	201.9
Lexicon	181.9
Millennium	205.2
Viscount	103.3
91-229Cn234 (Chris – high oil)	194.8
91-229Cn253 (Fatso – high oil	192.2
93-76Cn1/1	224.8
95-56Acn3 (MM/Jalna)	236.3
Overall Mean	187.4
CV%	**13.7**
Variety SED	**18.21**
p value	**<0.001**
DF	**48**

Table 23. Harvest data

Variety	Grain yield t/ha	Specific weight kg/hl
Birnam	6.35	52.37
Expression	5.97	64.23
Gerald	7.49	54.40
Grafton	4.75	65.33
Harpoon	5.59	67.23
Hendon	5.17	62.38
Icon	5.03	66.92
Image	3.80	51.78
Jalna	6.98	54.51
Kingfisher	7.30	53.01
Krypton	6.02	63.32
Lexicon	4.65	64.47
Millennium	7.28	52.16
Viscount	6.31	51.96
91-229Cn234 (Chris – high oil)	3.93	60.92
91-229Cn253 (Fatso – high oil	3.42	60.45
93-76Cn1/1	7.24	48.72
95-56Acn3 (MM/Jalna)	7.34	55.52
Overall Mean	5.80	58.32
CV%	**8.8**	**2.0**
Variety SED	**0.37**	**0.81**
p value	**<0.001**	**<0.001**
DF	**46**	**48**

Table 23. Whole plot lodging assessments

	Lodging assessments %
Variety	29th July
Birnam	10.00
Expression	8.75
Gerald	0.00
Grafton	3.50
Harpoon	1.50
Hendon	0.00
Icon	0.00
Image	*
Jalna	0.75
Kingfisher	67.00
Krypton	18.25
Lexicon	1.50
Millennium	12.50
Viscount	18.75
91-229Cn234 (Chris – high oil)	55.75
91-229Cn253 (Fatso – high oil	28.75
93-76Cn1/1	0.00
95-56Acn3 (MM/Jalna)	3.75
Overall Mean	13.57
CV%	**141.7**
Variety SED	**13.6**
p value	**<0.001**
DF	**48**

Year 2 (2002 harvest) results

Table 24. Plant populations

Variety	Autumn Plants/m^2
Buffalo	284.44
Dalguise	307.78
Expression	255.18
Gerald	297.04
Grafton	178.27
Harpoon	253.33
Hendon	252.59
Jalna	301.48
Kingfisher	287.04
Krypton	248.89
Lexicon	218.52
Millennium	271.48
91-229Cn234 (Chris – high oil)	247.78
94-116Cn4/1 (New husked dwarf)	308.52
95-205Acn1/2 (Large grained short naked)	273.70
95-56Acn3 (MM/Jalna)	275.56
96-140Cn1 (New high oil)	254.44
Overall Mean	266.82
CV%	**7.6**
Variety SED	**14.26**
p value	**<0.001**
DF	**46**

Table 25. Harvest data

Variety	Grain yield t/ha	Specific weight kg/hl	Thousand grain weight g
Buffalo	10.16	54.59	39.12
Dalguise	9.90	56.83	44.04
Expression	8.29	65.01	32.93
Gerald	9.54	56.54	39.00
Grafton	7.15	66.60	32.88
Harpoon	6.90	65.51	33.74
Hendon	7.87	63.53	28.54
Jalna	9.40	56.82	41.13
Kingfisher	10.29	56.76	46.11
Krypton	8.07	62.90	30.15
Lexicon	7.31	64.31	29.44
Millennium	10.07	53.71	49.47
91-229Cn234 (Chris – high oil)	5.54	64.14	23.92
94-116Cn4/1 (New husked dwarf)	9.98	53.54	38.44
95-205Acn1/2 (Large grained short naked)	6.74	65.50	35.17
95-56Acn3 (MM/Jalna)	9.54	57.00	49.39
96-140Cn1 (New high oil)	6.62	64.45	26.37
Overall Mean	8.45	60.41	36.32
CV%	**7.0**	**3.6**	**5.6**
Variety SED	**0.416**	**1.552**	**1.437**
p value	**<0.001**	**<0.001**	**<0.001**
DF	**45**	**46**	**46**

Table 26. Whole plot lodging assessments

	Lodging assessments %	
Variety	6th July	9th August
Buffalo	0.00	0.00
Dalguise	0.00	21.25
Expression	6.25	31.25
Gerald	0.00	0.00
Grafton	0.00	0.00
Harpoon	0.00	0.00
Hendon	0.00	1.00
Jalna	12.50	6.25
Kingfisher	0.00	23.75
Krypton	9.50	27.00
Lexicon	3.75	23.75
Millennium	0.00	2.50
91-229Cn234 (Chris – high oil)	19.25	1.25
94-116Cn4/1 (New husked dwarf)	0.00	0.00
95-205Acn1/2 (Large grained short naked)	0.00	1.25
95-56Acn3 (MM/Jalna)	0.00	0.00
96-140Cn1 (New high oil)	0.00	6.25
Overall Mean	3.11	8.82
CV%	**203.0**	**117.8**
Variety SED	**4.313**	**7.16**
p value	**<0.001**	**<0.001**
DF	**46**	**46**

Year 3 (2003 harvest) results

Table 27. Autumn plant populations

Variety	Plants/m^2
Ayr	263.70
Buffalo	254.07
Dalguise	278.15
Expression	278.52
Gerald	244.07
Grafton	234.44
Hendon	433.70
Jalna	275.56
Kingfisher	259.63
Millennium	262.22
91-229Cn234 (Chris – high oil)	298.15
94-116Cn4/1 (New husked dwarf)	275.56
95-240Cn 3/1/1/1	268.89
95-27 Cn5/1	317.78
95-75 Cn5/1	292.96
Overall Mean	282.49
CV%	**6.9**
Variety SED	**13.77**
p value	**<0.001**
DF	**40**

Table 28. Pre-harvest Biomass, Crop dry matter t/ha

Variety	Straw	Grain	Chaff	Total
Ayr	6.78	4.24	1.35	12.38
Buffalo	8.36	7.89	2.47	18.72
Dalguise	7.85	5.34	2.57	15.76
Expression	9.27	7.70	2.10	19.06
Gerald	8.32	3.88	2.09	14.29
Grafton	8.29	4.43	0.93	13.65
Hendon	5.95	4.66	2.25	12.87
Jalna	7.91	7.18	1.22	16.31
Kingfisher	8.30	5.54	2.24	16.08
Millennium	8.08	6.40	3.39	17.87
91-229Cn234 (Chris – high oil)	8.23	2.76	1.40	12.39
94-116Cn4/1 (New husked dwarf)	6.56	6.85	2.36	15.77
95-240Cn 3/1/1/1	10.50	5.33	2.43	18.26
95-27 Cn5/1	7.79	5.87	1.86	15.52
95-75 Cn5/1	7.10	3.69	0.90	11.70
Overall Mean	7.94	5.44	2.07	15.45
CV%	**15.1**	**24.3**	**44.3**	**15.8**
Variety SED	**0.976**	**1.080**	**0.747**	**1.996**
p value	**0.021**	**0.001**	**NS**	**0.006**
DF	**25**	**25**	**25**	**25**

Table 29. Pre-harvest Biomass, yield components

Variety	Harvest Index	Thousand grain weight g @ 85%	Grain weight (g)/ear	Grain number /ear	Ear number /m^2
Ayr	34.55	36.16	0.71	22.30	624.77
Buffalo	41.47	33.84	2.02	69.16	393.84
Dalguise	33.77	32.52	0.74	26.31	736.98
Expression	40.46	31.48	1.43	53.06	550.33
Gerald	26.75	29.28	0.69	26.98	571.21
Grafton	32.24	32.66	1.19	41.46	384.60
Hendon	36.20	36.04	1.05	32.52	498.46
Jalna	44.72	33.67	1.68	57.19	447.51
Kingfisher	34.59	31.55	1.54	56.77	360.65
Millennium	35.84	22.21	0.91	47.81	711.73
91-229Cn234 (Chris – high oil)	20.90	23.27	0.71	36.64	362.09
94-116Cn4/1 (New husked dwarf)	43.45	34.58	1.69	56.06	418.25
95-240Cn 3/1/1/1	29.24	25.28	1.34	63.75	420.77
95-27 Cn5/1	34.0	30.59	1.06	41.70	538.54
95-75 Cn5/1	30.29	27.12	0.69	29.50	472.93
Overall Mean	34.26	30.73	1.18	43.90	499.66
CV%	**15.9**	**16.8**	**28.6**	**27.8**	**23.4**
Variety SED	**4.46**	**4.206**	**0.271**	**9.97**	**95.4**
p value	**0.002**	**0.040**	**<0.001**	**<0.001**	**0.005**
DF	**39**	**39**	**39**	**39**	**39**

Table 30. Harvest data

Variety	Grain yield t/ha	Specific weight kg/hl	Thousand grain weight g
Ayr	7.92	55.21	36.00
Buffalo	8.66	50.18	31.24
Dalguise	8.43	56.28	34.93
Expression	6.34	63.14	27.19
Gerald	8.99	54.83	31.88
Grafton	6.82	63.86	29.75
Hendon	6.24	59.27	19.61
Jalna	8.21	56.00	31.58
Kingfisher	8.08	54.78	35.72
Millennium	8.04	55.42	38.49
91-229Cn234 (Chris – high oil)	3.87	63.74	20.54
94-116Cn4/1 (New husked dwarf)	8.35	54.38	29.78
95-240Cn 3/1/1/1	6.29	66.65	23.69
95-27 Cn5/1	9.33	55.36	32.31
95-75 Cn5/1	8.51	55.05	30.72
Overall Mean	7.60	57.61	30.23
CV%	**7.5**	**5.8**	**9.0**
Variety SED	**0.402**	**2.36**	**1.934**
p value	**<0.001**	**<0.001**	**<0.001**
DF	**39**	**39**	**39**

Table 31. Whole plot lodging assessments

	Lodging assessments %		
Variety	20th June	17th July	29th July
Ayr	3.75	67.50	77.50
Buffalo	0.00	0.00	7.50
Dalguise	0.00	70.00	70.00
Expression	57.50	62.50	61.25
Gerald	0.00	45.00	30.00
Grafton	0.00	1.25	30.00
Hendon	0.00	2.50	11.25
Jalna	22.50	51.25	47.50
Kingfisher	25.00	71.25	45.00
Millennium	10.00	66.25	70.00
91-229Cn234 (Chris – high oil)	76.25	75.00	95.00
94-116Cn4/1 (New husked dwarf)	0.00	13.75	27.50
95-240Cn 3/1/1/1	29.25	40.00	47.50
95-27 Cn5/1	11.20	63.90	39.70
95-75 Cn5/1	17.80	43.90	54.70
Overall Mean	16.90	44.90	47.60
CV%	**72.4**	**38.1**	**40.2**
Variety SED	**8.64**	**12.09**	**13.53**
p value	**<0.001**	**<0.001**	**<0.001**
DF	**40**	**40**	**40**

APPENDIX 3

Variety x nitrogen/fungicide interaction experiments

Materials and Methods

In 2001, three winter naked oat varieties (Grafton, Icon and Hendon) were sown at two seed rates 200 and 400 seeds m^{-2} at two sites Rosemaund and Caythorpe. At Midlothian two spring oat varieties (Bullion and Neon) were sown at the same seed rates.

Three nitrogen treatments with different rates and timings of prilled ammonium nitrate were applied as follows:

	Ammonium Nitrate kg N/ha			Foliar Urea kg N/ha	Total Rate kg N/ha
Trt No.	GS 30	GS 31/2	GS 33/7	GS65	
1	80	0	40	0	120
2	40	40	40	0	120
3	40	40	40	60	180

Three fungicide treatment programmes were applied as follows:

Treatment No.	Product	Rate l/ha	Timing
1	Alto 100 + Corbel	0.4 + 0.5	GS 31/2 & GS 39
2	Mantra	1.0	GS 31/2
3	Mantra	1.0	GS 31/2 & GS 39

The experimental design was a split plot plus three way factorial with varieties as main plots, seed rate, nitrogen and fungicide treatments as randomised sub-plots with three replicates.

In 2002, three winter naked oat varieties (Grafton, Hendon and Expression) were sown at two seed rates 200 and 400 seeds m^{-2} at three sites Rosemaund, Abbots Ripton and Kirkness. Due to poor plant establishment associated with sowing problems the Abbots Ripton site had to be abandoned.

Five nitrogen/fungicide treatments with different type and timings of nitrogen were applied as follows:

Treatment No.	Ammonium Nitrate kg N/ha		Foliar Urea kg N/ha	Fungicide l/ha	
	GS 30/31	GS 32	GS 65	GS31/2	GS 39
1	120	-	-	Alto 100 0.4 Corbel 0.5	Alto 100 0.4 Corbel 0.5
2	40	80	-	Alto 100 0.4 Corbel 0.5	Alto 100 0.4 Corbel 0.5
3	40	40	40	Alto 100 0.4 Corbel 0.5	Alto 100 0.4 Corbel 0.5
4	40	40	60	Alto 100 0.4 Corbel 0.5	Alto 100 0.4 Corbel 0.5
5	40	40	40	Opera 1.0	Opera 1.0

The experimental design was a split plot plus two way factorial with varieties as main plots, seed rate and nitrogen/fungicide treatments as randomised sub-plots with three replicates.

In 2003, three winter oat varieties (Hendon, Buffalo and Millenium) were sown at a single seed rate of 400 seeds m^{-2} at two sites Rosemaund, Abbots Ripton.

Three nitrogen treatments with different rates and timings of prilled ammonium nitrate were applied at Rosemaund as follows:

Treatment	Ammonium Nitrate N kg/ha GS 30	GS 32	Total N kg /ha
1	40	60	100 (RB 209 rec + 30)
2	40	120	160 (RB 209 rec + 90)
3	40	180	220 (RB 209 rec + 150)

Six nitrogen treatments with different rates and timings of prilled ammonium nitrate were applied at Abbots Ripton as follows:

Treatment	Ammonium Nitrate N kg/ha GS 30	GS 32	GS 65	Foliar Urea N kg/ha GS 65	Total N kg /ha
1	40	60	0	0	100 (RB 209 rec - 30)
2	40	90	0	0	130 (RB 209 rec)
3	40	90	0	30	160 (RB 209 rec + 30)
4	40	90	30	0	160 (RB 209 rec + 30)
5	40	120	0	0	160 (RB 209 rec + 30)
6	40	150	0	0	190 (RB 209 rec + 60)

The experimental design was a split plot plus factorial with nitrogen as main plots and variety as randomised sub-plots with three replicates.

In the detailed field experiments at ADAS Rosemaund crop establishment was assessed pre-tillering with the number of plants counted in 10m x 1m row lengths per plot. Weekly measurements of light interception with ceptometers (Sunfleck meters) allowed canopy development to be monitored through the growing season. Crop growth assessed as both dry matter and green area index measurements were taken from a sub set of treatments and experiments at stem extension (GS31) and when 50% of all the main shoots reached mid-anthesis (GS65). An assessment of the components of yield was made on samples taken immediately pre-harvest. Grain yield was measured using a plot combine from a harvest area of 10m by 2m. Grain specific weight was measured using a manual chondrometer, grain moisture content was calculated after oven drying at $80^{O}C$ for 48 hrs. Thousand-grain weight was measured using a numigral grain counter. At the non-ADAS sites crop establishment and grain yield were assessed using the same methodology.

Year 1 (2001 harvest) results

ADAS Rosemaund Site

Table 32. Autumn plant populations

Variety	Seedrate Seeds m^{-2}	Plants/m^2
Grafton	200	182.96
	400	298.27
Grafton	Mean	240.62
Icon	200	186.67
	400	296.79
Icon	Mean	241.73
Hendon	200	208.64
	400	305.18
Hendon	Mean	256.91
		246.42
200	Mean	192.76
400	Mean	300.08
Overall	Mean	
CV%		**6.9**
Variety SED		**7.55**
p value		**NS**
DF		**4**
Seedrate SED		**8.00**
p value		**<0.001**
Interaction SED		**12.38**
p value		**NS**
DF		**6**

Table 33. Yield t/ha @ 85% dry matter

Yield (t/ha)			Nitrogen		
Variety	Seedrate	Fungicide	80 + 40 N	40 + 80 N	40 + 80+60 N
Grafton	200	Alto/Corbel	5.93	6.28	6.78
		Mantra x1	6.60	6.65	6.71
		Mantra x2	6.18	6.89	6.53
	200 Mean		6.24	6.61	6.68
	400	Alto/Corbel	6.34	6.17	6.88
		Mantra x1	6.31	6.35	6.83
		Mantra x2	6.73	6.65	7.07
	400 Mean		6.46	6.39	6.93
Grafton Mean			6.35	6.50	6.80
Hendon	200	Alto/Corbel	7.30	7.03	6.95
		Mantra x1	7.40	7.10	7.19
		Mantra x2	7.17	6.97	7.63
	200 Mean		7.29	7.03	7.26
	400	Alto/Corbel	7.15	7.08	6.81
		Mantra x1	7.49	7.13	7.40
		Mantra x2	7.51	7.48	7.71
	400 Mean		7.38	7.23	7.31
Hendon Mean			7.34	7.13	7.28
Icon	200	Alto/Corbel	7.64	7.12	7.21
		Mantra x1	7.24	7.45	7.28
		Mantra x2	7.33	7.29	7.69
	200 Mean		7.41	7.29	7.39
	400	Alto/Corbel	7.46	7.71	7.67
		Mantra x1	7.75	7.51	7.79
		Mantra x2	7.39	7.70	7.73
	400 Mean		7.54	7.64	7.73
Icon Mean			7.47	7.47	7.56
Overall Mean			7.05	7.03	7.22
		Variety p value		**0.020**	
		SED		**0.201**	
		df		**4**	
		Seed rate p value		**0.012**	
		SED		**0.0621**	
		Nitrogen p value		**0.034**	
		SED		**0.076**	
		Fungicide p value		**0.012**	
		SED		**0.076**	
		All interactions		**NS**	
		df		**102**	
		cv%		**5.6**	

Table 34. Specific Weight kg/hl

Specific Weight (kg/hl)			Nitrogen		
Variety	Seedrate	Fungicide	80 + 40 N	40 + 80 N	40 + 80+60 N
Grafton	200	Alto/Corbel	65.64	64.42	63.88
		Mantra x1	64.84	63.85	63.00
		Mantra x2	65.07	64.12	63.71
	200 Mean		65.19	64.13	63.53
	400	Alto/Corbel	63.84	64.47	64.08
		Mantra x1	64.82	63.33	64.04
		Mantra x2	64.85	64.71	62.92
	400 Mean		64.50	64.17	63.68
Grafton Mean			64.84	64.15	63.61
Hendon	200	Alto/Corbel	58.62	59.96	59.94
		Mantra x1	58.30	59.50	59.08
		Mantra x2	59.80	59.65	59.65
	200 Mean		58.91	59.70	59.56
	400	Alto/Corbel	59.40	59.83	59.74
		Mantra x1	58.81	60.66	61.13
		Mantra x2	59.32	60.06	59.49
	400 Mean		59.18	60.18	60.12
Hendon Mean			59.04	59.94	59.84
Icon	200	Alto/Corbel	63.45	61.71	63.18
		Mantra x1	63.47	64.28	63.48
		Mantra x2	64.00	63.15	62.27
	200 Mean		63.64	63.05	62.98
	400	Alto/Corbel	63.94	63.15	63.71
		Mantra x1	63.98	63.95	63.75
		Mantra x2	63.55	63.29	62.85
	400 Mean		63.82	63.46	63.43
Icon Mean			63.73	63.26	63.20
Overall Mean			62.54	62.45	62.22
		Variety p value		**0.002**	
		SED		**0.560**	
		df		**4**	
		Seed rate p value		**NS**	
		SED		**0.166**	
		Nitrogen p value		**NS**	
		SED		**0.204**	
		Fungicide p value		**NS**	
		SED		**0.204**	
		Variety x Nitrogen p value		**<0.001**	
		SED		**0.630**	
		All other interactions		**NS**	
		df		**102**	
		cv%		**1.7**	

Nitrogen x Variety trial
SW Caythorpe Site

Table 35. Plant populations (10 May 2001)

Plants/m2		N applied		
Variety	Seed rate	N: 40+20	N: 40+80	N: 40+80+60
Grafton	200	131.58	115.09	120.18
	400	199.42	196.20	197.66
Grafton Mean		165.50	159.33	158.92
Napoleon	200	120.76	117.54	125.15
	400	216.37	220.47	222.51
Napoleon Mean		168.57	169.01	173.83
Icon	200	127.78	127.19	129.82
	400	214.04	211.23	222.22
Icon Mean		170.91	173.88	176.02
Grand Mean		168.32	167.05	169.59
	Variety p value	**0.026**		
	SED	**4.74**		
	Seed rate p value	**<0.001**		
	SED	**3.87**		
	Nitrogen p value	**NS**		
	SED	**4.74**		
	All interactions	**NS**		
	df	**64**		
	cv%	**12.0**		

Table 36. Yield t/ha @ 85% dry matter

Yield (t/ha)			Nitrogen		
Variety	Seedrate	Fungicide	40+20 N	40+80 N	40+80+60 N
Grafton	200	Alto/Corbel	5.12	4.76	5.10
		Mantra x1	4.30	4.85	5.27
		Mantra x2	5.41	5.08	5.03
	200 Mean		4.94	4.92	5.13
	400	Alto/Corbel	4.62	5.12	5.08
		Mantra x1	4.72	5.12	5.14
		Mantra x2	4.70	5.03	5.22
	400 Mean		4.68	5.09	5.15
Grafton Mean			4.81	5.01	5.14
Hendon	200	Alto/Corbel	4.47	4.70	4.83
		Mantra x1	4.93	4.70	4.76
		Mantra x2	4.76	5.01	5.10
	200 Mean		4.72	4.80	4.90
	400	Alto/Corbel	4.62	4.99	5.24
		Mantra x1	4.68	5.12	5.24
		Mantra x2	4.62	5.16	5.10
	400 Mean		4.64	5.09	5.19
Hendon Mean			4.68	4.95	5.04
Icon	200	Alto/Corbel	5.01	4.82	4.78
		Mantra x1	4.01	4.36	4.55
		Mantra x2	4.38	4.89	5.24
	200 Mean		4.47	4.65	4.85
	400	Alto/Corbel	4.38	4.82	5.10
		Mantra x1	4.55	4.91	4.62
		Mantra x2	4.51	4.99	5.16
	400 Mean		4.48	4.92	4.96
Icon Mean			4.47	4.79	4.91
Overall Mean			4.66	4.92	5.03
		Fungicide p value	**NS**		
		SED	**0.135**		
		df	**4**		
		Variety p value	**0.019**		
		SED	**0.091**		
		Seed rate p value	**NS**		
		SED	**0.074**		
		Nitrogen p value	**<0.001**		
		SED	**0.091**		
		All interactions	**NS**		
		df	**98**		
		cv%	**9.7**		

Nitrogen x Variety trial

SAG Midlothian Site

Table 37. Yield t/ha @ 85% dry matter

Yield (t/ha)			Nitrogen		
Variety	Seedrate	Fungicide	70 kgN	100 kgN	100kgN +30FU
Bullion	200	Alto/Corbel	3.81	4.39	4.99
		Mantra x1	4.33	4.30	4.48
		Mantra x2	4.05	4.00	4.36
	200 Mean		4.06	4.23	4.61
	400	Alto/Corbel	4.01	4.45	4.53
		Mantra x1	3.84	4.53	4.46
		Mantra x2	3.90	4.49	4.67
	400 Mean		3.92	4.49	4.55
Bullion Mean			3.99	4.36	4.58
Neon	200	Alto/Corbel	4.17	4.98	4.72
		Mantra x1	4.19	4.80	4.89
		Mantra x2	4.39	4.79	4.94
	200 Mean		4.25	4.86	4.85
	400	Alto/Corbel	4.25	5.32	5.09
		Mantra x1	4.64	5.23	5.39
		Mantra x2	4.66	5.01	4.67
	400 Mean		4.52	5.19	5.05
Neon Mean			4.38	5.02	4.95
Overall Mean			4.19	4.69	4.77
		Variety p value	**<0.001**		
		SED	**0.071**		
		Seed rate p value	**0.051**		
		SED	**0.071**		
		Nitrogen p value	**<0.001**		
		SED	**0.087**		
		Fungicide p value	**NS**		
		SED	**0.087**		
		All interactions	**NS**		
		df	**70**		
		cv%	**8.2**		

Table 37. Ear numbers/m^2

Ear numbers/m^2			Nitrogen		
Variety	Seedrate	Fungicide	70 kgN	100 kgN	100kgN +30FU
Bullion	200	Alto/Corbel	313.3	350.0	313.3
		Mantra x1	260.0	306.7	266.7
		Mantra x2	290.0	296.7	293.3
	200 Mean		287.8	317.8	291.1
	400	Alto/Corbel	320.0	390.0	356.7
		Mantra x1	310.0	360.0	333.3
		Mantra x2	296.7	333.3	333.3
	400 Mean		308.9	361.1	341.1
Bullion Mean			298.3	339.4	316.1
Neon	200	Alto/Corbel	256.7	340.0	310.0
		Mantra x1	263.3	326.7	346.7
		Mantra x2	253.3	303.3	330.0
	200 Mean		257.8	323.3	328.9
	400	Alto/Corbel	300.0	383.3	320.0
		Mantra x1	323.3	363.3	370.0
		Mantra x2	310.0	366.7	330.0
	400 Mean		311.1	371.1	340.0
Neon Mean			284.4	347.2	334.4
Overall Mean			291.4	343.3	325.3
		Variety p value	**NS**		
		SED	**7.01**		
		Seed rate p value	**<0.001**		
		SED	**7.01**		
		Nitrogen p value	**<0.001**		
		SED	**8.58**		
		Fungicide p value	**NS**		
		SED	**8.58**		
		All interactions	**NS**		
		df	**70**		
		cv%	**11.4**		

Year 2 (2002 harvest) results

ADAS Rosemaund Site

Table 38. Autumn plant populations

Variety	Seedrate Seeds m^{-2}	Plants/m^2
Expression	200	183.21
	400	272.59
Expression	Mean	227.90
Grafton	200	114.57
	400	179.75
Grafton	Mean	147.16
Hendon	200	160.49
	400	288.89
Hendon	Mean	224.69
200	Mean	152.76
400	Mean	247.08
Overall	Mean	199.92
CV%		**10.7**
Variety SED		**14.38**
p value		**0.008**
DF		**4**
Seedrate SED		**10.06**
p value		**<0.001**
Interaction SED		**18.94**
p value		**NS**
DF		**6**

Figure x. Percentage Photosynthetic Active Radiation absorbed by the crop in five nitrogen treatments mean of two varieties sown at 200 seeds/m^2.

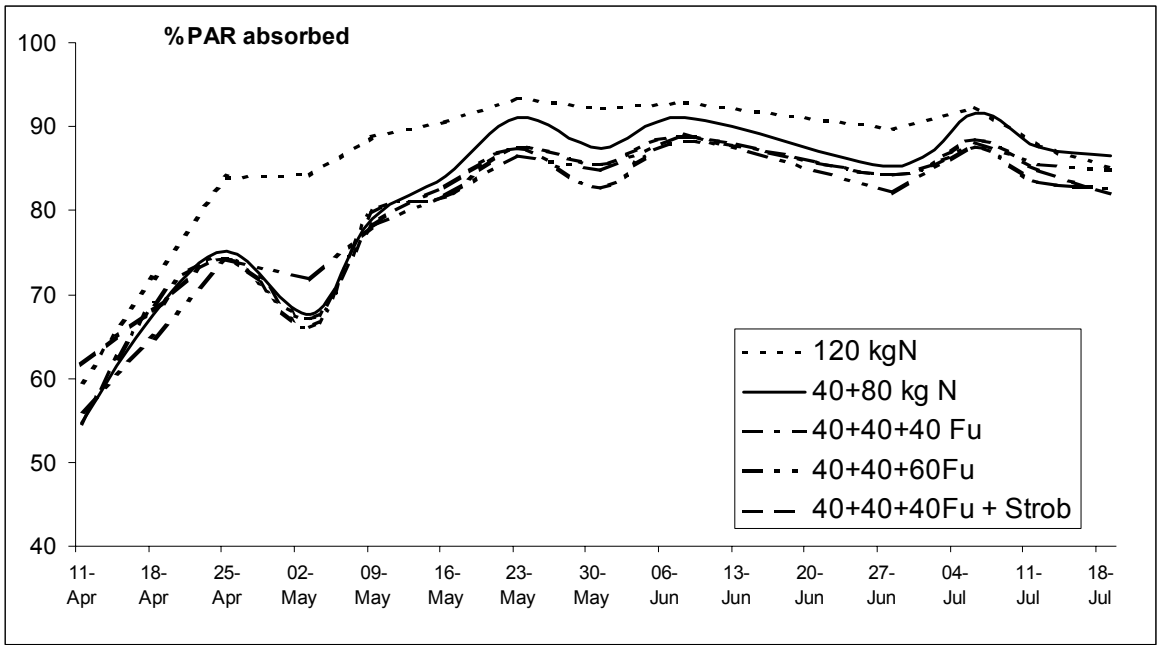

Figure x. Percentage Photosynthetic Active Radiation absorbed by the crop in five nitrogen treatments mean of two varieties sown at 400 seeds/m^2.

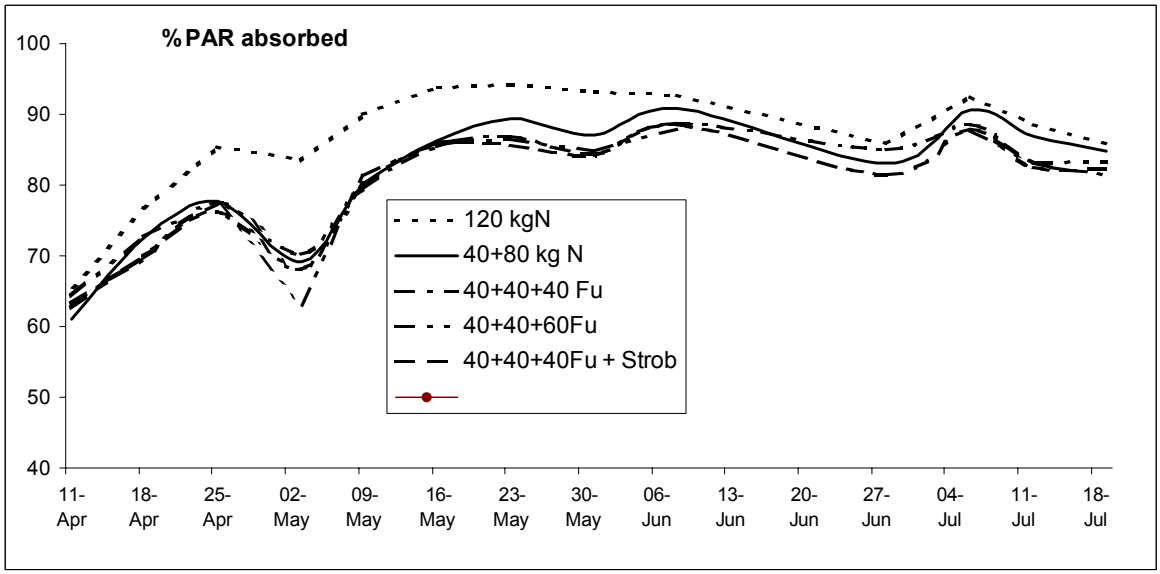

Table 39. GS31 Biomass, Canopy size

					Green Area Index		
Variety	Nitrogen kg/ha N	Seedrate Seeds m^{-2}	Fertile shoots/m^2	Dying shoots/m^2	Leaf	Stem	Total
Expression	40 GS30	200	641.89	156.46	5.41	0.39	5.81
		400	793.26	145.66	4.73	0.31	5.04
	40 GS30	Mean	717.58	151.06	5.07	0.35	5.42
	120 GS30	200	881.99	122.51	4.48	0.32	4.80
		400	955.21	131.16	4.96	0.39	5.35
	120 GS30	Mean	918.60	126.83	4.72	0.36	5.08
Expression		Mean	818.09	138.95	4.90	0.35	5.25
Grafton	40 GS30	200	478.83	149.00	4.01	0.25	4.25
		400	527.14	186.56	3.87	0.25	4.12
	40 GS30	Mean	502.98	167.78	3.94	0.25	4.19
	120 GS30	200	664.53	139.99	4.52	0.29	4.80
		400	774.30	159.80	3.08	0.19	3.27
	120 GS30	Mean	719.41	149.89	3.80	0.24	4.04
Grafton		Mean	611.20	158.84	3.87	0.24	4.11
Hendon	40 GS30	200	938.06	155.62	4.95	0.35	5.30
		400	814.22	245.33	4.94	0.31	5.25
	40 GS30	Mean	876.14	200.48	4.94	0.33	5.27
	120 GS30	200	926.78	69.72	6.23	0.45	6.69
		400	1141.86	105.96	6.60	0.49	7.09
	120 GS30	Mean	1034.32	87.84	6.42	0.47	6.89
Hendon		Mean	955.23	144.16	5.68	0.40	6.08
		Overall mean	794.84	147.31	4.82	0.33	5.15
		CV%					
		Variety SED	**89.5**	**31.5**	**0.690**	**0.061**	
		p value	**0.044**	**NS**	**NS**	**NS**	**NS**
		DF	**4**	**4**	**4**	**4**	**4**
		Seedrate SED	**46.1**	**20.5**	**0.440**	**0.043**	
		p value	**NS**	**NS**	**NS**	**NS**	**NS**
		Nitrogen SED	**46.1**	**20.5**	**0.440**	**0.043**	
		p value	**<0.001**	**0.021**	**NS**	**NS**	**NS**
		Variety x Seedrate SED	**105.9**	**40.2**	**0.876**	**0.081**	
		p value	**NS**	**NS**	**NS**	**NS**	**NS**
Variety x Nitrogen SED			**105.9**	**40.2**	**0.876**	**0.081**	
		p value	**NS**	**NS**	**NS**	**NS**	**NS**
		Seedrate x Nitrogen SED	**65.2**	**28.9**	**0.623**	**0.061**	
		p value	**NS**	**NS**	**NS**	**NS**	**NS**
		Variety x Seedrate x Nitrogen SED	**132.6**	**18.68**	**1.162**	**0.110**	
		p value	**NS**	**NS**	**NS**	**NS**	**NS**
		DF	**18**	**18**	**18**	**18**	**18**

Table 40. GS31 Biomass, Crop dry matter t/ha

Variety	Nitrogen kg/ha N	Seedrate Seeds m^{-2}	Green Leaf	Green Stem	Dead leaf	Total
Expression	40 GS30	200	2.56	1.26	0.19	4.18
		400	2.95	1.37	0.21	4.67
	40 GS30	Mean	2.76	1.32	0.20	4.42
	120 GS30	200	2.86	1.60	0.15	4.74
		400	3.31	1.60	0.27	5.28
	120 GS30	Mean	3.08	1.60	0.21	5.01
Expression		Mean	2.92	1.46	0.20	4.72
Grafton	40 GS30	200	2.16	1.26	0.16	3.66
		400	2.56	1.48	0.21	4.44
	40 GS30	Mean	2.36	1.37	0.18	4.05
	120 GS30	200	2.38	1.39	0.11	4.03
		400	2.94	1.54	0.17	4.78
	120 GS30	Mean	2.66	1.47	0.14	4.40
Grafton		Mean	2.51	1.42	0.16	4.22
Hendon	40 GS30	200	2.76	1.52	0.15	4.51
		400	2.61	1.43	0.15	4.33
	40 GS30	Mean	2.69	1.48	0.15	4.42
	120 GS30	200	2.74	1.35	0.07	4.18
		400	3.07	1.57	0.11	4.79
	120 GS30	Mean	2.91	1.46	0.09	4.48
Hendon		Mean	2.80	1.47	0.12	4.45
		Overall mean	2.74	1.45	0.16	4.46
		CV%				
		Variety SED	**0.074**	**0.088**	**0.040**	**0.169**
		p value	**0.012**	**NS**	**NS**	**NS**
		DF	**4**	**4**	**4**	**4**
		Seedrate SED	**0.169**	**0.089**	**0.023**	**0.267**
		p value	**0.067**	**NS**	**0.042**	**0.078**
		Nitrogen SED	**0.169**	**0.089**	**0.023**	**0.267**
		p value	**NS**	**NS**	**NS**	**NS**
		Variety x Seedrate SED	**0.220**	**0.141**	**0.049**	**0.368**
		p value	**NS**	**NS**	**NS**	**NS**
Variety x Nitrogen SED			**0.220**	**0.141**	**0.049**	**0.368**
		p value	**NS**	**NS**	**NS**	**NS**
		Seedrate x Nitrogen SED	**0.239**	**0.127**	**0.032**	**0.378**
		p value	**NS**	**NS**	**NS**	**NS**
		Variety x Seedrate x Nitrogen SED	**0.366**	**0.210**	**0.063**	**0.591**
		p value	**NS**	**NS**	**NS**	**NS**
		DF	**18**	**18**	**18**	**18**

Table 41. GS65 Biomass, Shoot numbers

Variety	Nitrogen kg/ha N	Seedrate Seeds m^{-2}	Fertile shoots/m^2	Dying shoots/m^2
Grafton	40 GS30	200	293.34	33.12
		400	381.12	52.54
	40 GS30	Mean	337.23	42.83
	40 GS30 + 40 GS32 + 40 FU	200	214.37	24.88
		400	294.32	24.09
	40 GS30 + 40 GS32 + 40 FU	Mean	254.34	24.48
	120 GS30	200	247.18	36.44
		400	304.88	63.15
	120 GS30	Mean	276.03	49.80
Grafton		Mean	289.20	39.04
Hendon	40 GS30	200	421.37	73.71
		400	530.38	96.18
	40 GS30	Mean	475.87	84.94
	40 GS30 + 40 GS32 + 40 FU	200	276.80	63.57
		400	417.85	73.32
	40 GS30 + 40 GS32 + 40 FU	Mean	347.32	68.44
	120 GS30	200	373.27	89.90
		400	499.74	200.99
	120 GS30	Mean	436.50	145.45
Hendon		Mean	419.90	99.61
		Overall mean	354.55	69.32
		CV%	**19.9**	**64.5**
		Variety SED	**19.3**	**17.15**
		p value	**0.021**	**0.072**
		DF	**2**	**2**
		Seedrate SED	**23.6**	**14.90**
		p value	**<0.001**	**0.048**
		Nitrogen SED	**28.8**	**18.25**
		p value	**0.006**	**0.033**
		Variety x Seedrate SED	**30.4**	**22.72**
		p value	**NS**	**NS**
Variety x Nitrogen SED			**38.5**	**27.17**
		p value	**NS**	**NS**
		Seedrate x Nitrogen SED	**40.8**	**25.81**
		p value	**NS**	**NS**
		Variety x Seedrate x Nitrogen SED	**56.1**	**37.48**
		p value	**NS**	**NS**
		DF	**20**	**20**

Table 42. GS65 Biomass, Canopy size

			Green Area Index			
Variety	Nitrogen kg/ha N	Seedrate Seeds m^{-2}	Leaf	Stem	Ear	Total
Grafton	40 GS30	200	6.48	2.70	1.26	10.44
		400	6.73	2.54	1.25	10.52
	40 GS30	Mean	6.60	2.62	1.26	10.48
	40 GS30 + 40 GS32 + 40 FU	200	5.16	2.00	1.11	8.27
		400	5.34	2.08	1.07	8.48
	40 GS30 + 40 GS32 + 40 FU	Mean	5.25	2.04	1.09	8.38
	120 GS30	200	5.38	2.49	0.95	8.82
		400	4.87	2.14	1.05	8.06
	120 GS30	Mean	5.12	2.32	1.00	8.44
Grafton		Mean	5.66	2.32	1.11	9.10
Hendon	40 GS30	200	6.41	1.84	1.39	9.64
		400	7.56	2.37	1.77	11.70
	40 GS30	Mean	6.98	2.11	1.58	10.67
	40 GS30 + 40 GS32 + 40 FU	200	6.07	1.65	1.23	8.96
		400	5.78	1.89	1.38	9.05
	40 GS30 + 40 GS32 + 40 FU	Mean	5.93	1.77	1.31	9.00
	120 GS30	200	6.05	1.76	1.11	8.92
		400	6.19	2.21	1.26	9.66
	120 GS30	Mean	6.14	2.03	1.20	9.36
Hendon		Mean	6.36	1.97	1.37	9.70
		Overall mean	6.00	2.15	1.24	9.39
		CV%	**10.3**	**18.6**	**12.9**	
		Variety SED	**0.155**	**0.204**	**0.055**	
		p value	**0.041**	**NS**	**0.047**	**NS**
		DF	**2**	**2**	**2**	**2**
		Seedrate SED	**0.208**	**0.133**	**0.053**	
		p value	**NS**	**NS**	**0.045**	**NS**
		Nitrogen SED	**0.254**	**0.163**	**0.065**	
		p value	**<0.001**	**0.034**	**<0.001**	**NS**
		Variety x Seedrate SED	**0.259**	**0.244**	**0.077**	
		p value	**NS**	**NS**	**NS**	**NS**
Variety x Nitrogen SED			**0.332**	**0.278**	**0.093**	
		p value	**NS**	**NS**	**NS**	**NS**
		Seedrate x Nitrogen SED	**0.360**	**0.231**	**0.092**	
		p value	**NS**	**NS**	**NS**	**NS**
		Variety x Seedrate x Nitrogen SED	**0.490**	**0.361**	**0.131**	
		p value	**NS**	**NS**	**NS**	**NS**
		DF	**19**	**19**	**19**	**19**

Table 43. GS65 Biomass, Crop dry matter t/ha

Variety	Nitrogen kg/ha N	Seedrate Seeds m^{-2}	Green Leaf	Green Stem	Green Ear	Total
Grafton	40 GS30	200	2.50	10.03	4.61	17.48
		400	2.54	10.03	5.00	18.00
	40 GS30	Mean	2.52	10.03	4.80	17.74
	40 GS30 + 40 GS32 + 40 FU	200	2.28	9.92	4.41	16.84
		400	2.12	9.79	5.02	17.33
	40 GS30 + 40 GS32 + 40 FU	Mean	2.20	9.85	4.72	17.09
	120 GS30	200	2.08	10.03	3.71	16.55
		400	1.85	9.53	4.41	16.68
	120 GS30	Mean	1.97	9.78	4.06	16.61
Grafton		Mean	2.23	9.89	4.53	17.15
Hendon	40 GS30	200	2.65	7.85	5.04	16.02
		400	2.54	7.24	5.55	15.91
	40 GS30	Mean	2.59	7.54	5.30	15.96
	40 GS30 + 40 GS32 + 40 FU	200	2.40	7.40	4.64	14.80
		400	2.37	7.93	5.30	16.14
	40 GS30 + 40 GS32 + 40 FU	Mean	2.38	7.66	4.97	15.47
	120 GS30	200	2.50	8.19	4.67	16.40
		400	2.33	8.13	5.21	16.94
	120 GS30	Mean	2.42	8.16	4.94	16.67
Hendon		Mean	2.46	7.79	5.07	16.03
		Overall mean	2.35	8.84	4.80	16.59
		CV%	**8.3**	**8.2**	**9.6**	**8.0**
		Variety SED	**0.091**	**0.265**	**0.069**	**0.336**
		p value	**NS**	**0.016**	**0.016**	**0.080**
		DF	**2**	**2**	**2**	**2**
		Seedrate SED	**0.065**	**0.240**	**0.154**	**0.443**
		p value	**NS**	**NS**	**0.001**	**NS**
		Nitrogen SED	**0.079**	**0.294**	**0.189**	**0.543**
		p value	**<0.001**	**NS**	**0.027**	**NS**
		Variety x Seedrate SED	**0.111**	**0.358**	**0.169**	**0.556**
		p value	**NS**	**NS**	**NS**	**NS**
Variety x Nitrogen SED			**0.129**	**0.431**	**0.229**	**0.711**
		p value	**0.074**	**NS**	**NS**	**NS**
		Seedrate x Nitrogen SED	**0.112**	**0.416**	**0.267**	**0.768**
		p value	**NS**	**NS**	**NS**	**NS**
		Variety x Seedrate x Nitrogen SED	**0.171**	**0.599**	**0.352**	**1.046**
		p value	**NS**	**NS**	**NS**	**NS**
		DF	**20**	**20**	**20**	**20**

Table 44. Pre-harvest Biomass, Crop dry matter t/ha

Variety	Nitrogen kg/ha N	Seedrate Seeds m^{-2}	Straw	Grain	Chaff	Total
Expression	40 GS30	200	8.10	7.31	2.44	17.86
		400	8.13	7.46	2.31	17.90
	40 GS30	Mean	8.11	7.39	2.38	17.88
	40 GS30 + 40 GS32 + 40 FU	200	8.49	8.22	2.49	19.19
		400	7.12	7.19	2.17	16.47
	40 GS30 + 40 GS32 + 40 FU	Mean	7.80	7.70	2.33	17.83
	40 GS30 + 40 GS32 + 40 FU + Strobilurin	200	8.59	7.38	2.47	18.44
		400	7.72	7.24	2.36	17.32
	40 GS30 + 40 GS32 + 40 FU + Strobilurin	Mean	8.16	7.31	2.42	17.88
	40 GS30 + 40 GS32 + 60 FU	200	7.67	7.19	1.92	16.78
		400	8.16	8.16	2.56	18.88
	40 GS30 + 40 GS32 + 60 FU	Mean	7.92	7.67	2.24	17.83
	120 GS30	200	10.31	7.73	2.26	20.31
		400	7.74	5.21	1.06	14.01
	120 GS30	Mean	8.77	6.22	1.54	16.53
Expression		Mean	8.13	7.29	2.20	17.63
Grafton	40 GS30	200	7.48	6.59	2.15	16.22
		400	8.39	8.22	2.44	19.06
	40 GS30	Mean	7.94	7.40	2.30	17.64
	40 GS30 + 40 GS32 + 40 FU	200	7.51	7.05	2.27	16.84
		400	7.40	6.03	4.13	17.56
	40 GS30 + 40 GS32 + 40 FU	Mean	7.45	6.54	3.20	17.20
	40 GS30 + 40 GS32 + 40 FU + Strobilurin	200	7.08	6.71	2.20	15.98
		400	7.73	7.70	2.41	17.85
	40 GS30 + 40 GS32 + 40 FU + Strobilurin	Mean	7.41	7.20	2.30	16.91
	40 GS30 + 40 GS32 + 60 FU	200	6.97	6.07	2.16	15.19
		400	7.44	8.35	1.66	17.45
	40 GS30 + 40 GS32 + 60 FU	Mean	7.20	7.21	1.91	16.32
	120 GS30	200	8.62	7.04	2.10	17.76
		400	8.89	7.08	2.16	18.13
	120 GS30	Mean	8.76	7.06	2.13	17.95
Grafton		Mean	7.75	7.08	2.37	17.20
Hendon	40 GS30	200	6.08	7.10	3.14	16.33
		400	6.08	7.19	3.07	16.34
	40 GS30	Mean	6.08	7.15	3.10	16.33
	40 GS30 + 40 GS32 + 40 FU	200	5.72	7.55	3.07	16.35
		400	5.35	6.89	2.73	14.96
	40 GS30 + 40 GS32 + 40 FU	Mean	5.53	7.22	2.90	15.65
	40 GS30 + 40 GS32 + 40 FU + Strobilurin	200	8.38	9.74	4.03	22.15
		400	5.76	7.90	2.87	16.53
	40 GS30 + 40 GS32 + 40 FU + Strobilurin	Mean	7.07	8.82	3.45	19.34
	40 GS30 + 40 GS32 + 60 FU	200	6.73	7.10	3.74	17.57

		400	6.58	8.47	3.10	18.15
	40 GS30 + 40 GS32 + 60 FU	Mean	6.65	7.78	3.42	17.86
	120 GS30	200	7.76	7.58	2.71	18.04
		400	8.24	7.98	2.91	19.13
	120 GS30	Mean	8.00	7.78	2.81	18.59
Hendon		Mean	6.67	7.75	3.14	17.55
		Overall mean	7.51	7.38	2.57	17.46
		CV%	**14.4**	**14.7**	**33.7**	**12.3**
		Variety SED	**0.497**	**0.201**	**0.126**	**0.657**
		p value	**0.080**	**0.068**	**0.004**	**NS**
		DF	**4**	**4**	**4**	**4**
		Seedrate SED	**0.230**	**0.229**	**0.183**	**0.452**
		p value	**NS**	**NS**	**NS**	**NS**
		Nitrogen SED	**0.363**	**0.362**	**0.289**	**0.715**
		p value	**<0.001**	**NS**	**NS**	**NS**
		Variety x Seedrate SED	**0.571**	**0.345**	**0.257**	**0.860**
		p value	**0.065**	**0.072**	**NS**	**0.012**
Variety x Nitrogen SED			**0.750**	**0.595**	**0.465**	**1.29**
		p value	**NS**	**NS**	**NS**	**NS**
		Seedrate x Nitrogen SED	**0.513**	**0.511**	**0.409**	**1.011**
		p value	**NS**	**0.007**	**NS**	**0.071**
		Variety x Seedrate x Nitrogen SED	**0.979**	**0.864**	**0.683**	**1.787**
		p value	**NS**	**NS**	**NS**	**0.098**
		DF	**53**	**53**	**53**	**53**

Table 45. Pre-harvest Biomass, Yield components

Variety	Nitrogen kg/ha N	Seedrate Seeds m^{-2}	Harvest Index	Grain number /ear	Ear number /m^2
Expression	40 GS30	200	40.99	76.11	362.33
		400	41.69	60.36	492.42
	40 GS30	Mean	41.34	68.23	427.37
	40 GS30 + 40 GS32 + 40 FU	200	42.74	91.14	325.64
		400	43.66	58.59	457.89
	40 GS30 + 40 GS32 + 40 FU	Mean	43.20	74.86	391.76
	40 GS30 + 40 GS32 + 40 FU + Strobilurin	200	40.01	70.76	361.00
		400	41.77	65.46	414.20
	40 GS30 + 40 GS32 + 40 FU + Strobilurin	Mean	40.89	68.11	387.60
	40 GS30 + 40 GS32 + 60 FU	200	42.73	79.41	338.36
		400	43.24	61.02	465.54
	40 GS30 + 40 GS32 + 60 FU	Mean	42.98	70.22	401.95
	120 GS30	200	38.04	69.62	360.64
		400	37.23	58.52	328.85
	120 GS30	Mean	37.55	64.07	344.74
Expression		Mean	41.32	69.10	390.69
Grafton	40 GS30	200	40.59	99.68	250.48
		400	43.28	95.13	352.50
	40 GS30	Mean	41.94	97.41	301.49
	40 GS30 + 40 GS32 + 40 FU	200	42.00	101.58	247.86
		400	35.14	72.23	321.15
	40 GS30 + 40 GS32 + 40 FU	Mean	38.57	86.90	284.50
	40 GS30 + 40 GS32 + 40 FU + Strobilurin	200	42.09	107.64	231.24
		400	43.04	83.52	338.74
	40 GS30 + 40 GS32 + 40 FU + Strobilurin	Mean	42.57	95.58	284.99
	40 GS30 + 40 GS32 + 60 FU	200	39.70	103.95	227.19
		400	48.68	101.63	299.88
	40 GS30 + 40 GS32 + 60 FU	Mean	44.19	102.79	263.54
	120 GS30	200	39.69	92.19	285.66
		400	39.12	68.32	392.08
	120 GS30	Mean	39.41	80.26	338.87
Grafton		Mean	41.33	92.59	294.68
Hendon	40 GS30	200	43.86	91.71	356.68
		400	44.01	71.24	498.52
	40 GS30	Mean	43.93	81.48	427.60
	40 GS30 + 40 GS32 + 40 FU	200	46.40	87.56	356.38
		400	45.93	78.18	361.37
	40 GS30 + 40 GS32 + 40 FU	Mean	46.17	82.87	358.88
	40 GS30 + 40 GS32 + 40 FU + Strobilurin	200	43.96	91.02	442.08
		400	47.70	75.21	457.66
	40 GS30 + 40 GS32 + 40 FU + Strobilurin	Mean	45.83	83.12	449.87

	40 GS30 + 40 GS32 + 60 FU	200	40.64	90.60	326.37
		400	46.63	71.38	503.67
	40 GS30 + 40 GS32 + 60 FU	Mean	43.64	80.99	415.02
	120 GS30	200	42.13	90.04	380.37
		400	41.72	76.47	498.76
	120 GS30	Mean	41.92	83.26	439.56
Hendon		Mean	44.30	82.34	418.19
		Overall mean	42.33	81.34	367.85
		CV%	**10.2**	**15.3**	**17.31**
		Variety SED	**1.039**	**4.25**	**8.21**
		p value	**0.067**	**0.013**	**<0.001**
		DF	**4**	**4**	**4**
		Seedrate SED	**0.905**	**2.62**	**13.41**
		p value	**NS**	**<0.001**	**<0.001**
		Nitrogen SED	**1.430**	**4.15**	**21.21**
		p value	**0.063**	**NS**	**0.052**
		Variety x Seedrate SED	**1.519**	**5.33**	**18.36**
		p value	**NS**	**NS**	**NS**
Variety x Nitrogen SED			**2.447**	**7.70**	**33.86**
		p value	**NS**	**NS**	**NS**
		Seedrate x Nitrogen SED	**2.023**	**5.87**	**29.99**
		p value	**NS**	**NS**	**NS**
		Variety x Seedrate x Nitrogen SED	**3.482**	**10.54**	**49.96**
		p value	**NS**	**NS**	**NS**
		DF	**53**	**54**	**54**

Table 46. Yield t/ha @ 85% dry matter

Yield (t/ha)		Nit/Fung Treatment				
Variety	Seedrate	120 kgN	40+80 kg N	40+40+40 Fu	40+40+60Fu	40+40+40Fu + Strob
Expression	200	7.24	8.14	7.31	7.46	7.98
	400	7.42	8.34	7.94	8.05	7.91
Expression Total		7.33	8.24	7.62	7.75	7.94
Grafton	200	6.77	6.98	6.76	6.95	6.88
	400	8.03	8.11	7.47	7.35	7.05
Grafton Total		7.40	7.54	7.11	7.15	6.97
Hendon	200	7.88	7.54	7.67	7.63	8.06
	400	8.31	8.08	8.28	8.30	8.11
Hendon Total		8.10	7.81	7.98	7.97	8.09
Grand Total		7.61	7.86	7.57	7.62	7.67
Variety p value		**0.029**				
SED		**0.176**				
df		**4**				
Seed rate p value		**0.003**				
SED		**0.107**				
Var x Srate p value		**NS**				
SED		**0.219**				
df		**6**				
Nit/Fung p value		**NS**				
SED		**0.145**				
Var x Nit/Fung p value		**0.058**				
SED		**0.286**				
df		**24**				
Srate x Nit/Fung p value		**NS**				
SED		**0.227**				
Var x Srate x Nit/Fung p value		**NS**				
SED		**0.417**				
df		**24**				
cv%		**6.9**				

Table 47. Specific weight kg/hl

Specific Weight (kg/hl)		Nit/Fung Treatment				
Variety	Seedrate	120 kgN	40+80 kg N	40+40+40 Fu	40+40+60Fu	40+40+40Fu + Strob
Expression	200	68.17	68.00	68.21	68.05	68.15
	400	67.48	68.13	67.76	68.08	67.95
Expression Total		67.83	68.06	67.98	68.06	68.05
Grafton	200	70.07	68.96	69.58	69.91	70.38
	400	69.79	69.18	70.53	70.68	70.95
Grafton Total		69.93	69.07	70.05	70.30	70.66
Hendon	200	67.78	65.89	68.11	68.12	68.65
	400	67.16	66.42	67.85	68.52	68.96
Hendon Total		67.47	66.15	67.98	68.32	68.80
Grand Total		68.41	67.76	68.67	68.89	69.17
Variety p value		**<0.001**				
SED		**0.141**				
df		**4**				
Seed rate p value		**NS**				
SED		**0.087**				
Var x Srate p value		**0.051**				
SED		**0.176**				
df		**6**				
Nit/Fung p value		**<0.001**				
SED		**0.240**				
Var x Nit/Fung p value		**0.017**				
SED		**0.398**				
df		**24**				
Srate x Nit/Fung p value		**NS**				
SED		**0.302**				
Var x Srate x Nit/Fung p value		**NS**				
SED		**0.522**				
df		**24**				
cv%		**0.9**				

Table 48. Thousand grain weight g

Thousand grain weight (g)		Nit/Fung Treatment				
Variety	Seedrate	120 kgN	40+80 kg N	40+40+40 Fu	40+40+60Fu	40+40+40Fu + Strob
Expression	200	33.43	32.96	34.01	35.01	34.83
	400	32.79	32.86	33.87	34.73	33.49
Expression Total		33.11	32.91	33.94	34.87	34.16
Grafton	200	34.16	34.24	33.96	33.09	34.63
	400	31.99	28.33	34.45	35.95	34.36
Grafton Total		33.07	31.29	34.20	34.52	34.49
Hendon	200	28.16	27.48	25.28	30.33	30.73
	400	27.26	27.60	29.09	29.72	29.41
Hendon Total		27.71	27.54	27.18	30.02	30.07
Grand Total		31.30	30.58	31.78	33.14	32.91
Variety p value		**0.002**				
SED		**0.646**				
df		**4**				
Seed rate p value		**NS**				
SED		**0.443**				
Var x Srate p value		**NS**				
SED		**0.844**				
df		**6**				
Nit/Fung p value		**0.007**				
SED		**0.720**				
Var x Nit/Fung p value		**NS**				
SED		**1.289**				
df		**24**				
Srate x Nit/Fung p value		**NS**				
SED		**1.058**				
Var x Srate x Nit/Fung p value		**NS**				
SED		**1.891**				
df		**24**				
cv%		**7.7**				

Nitrogen x Variety x Seedrate trial

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Table 49. Yield t/ha @ 85% dry matter

Yield (t/ha)		Nit/Fung Treatment				
Variety	Seedrate	120 kgN	40+80 kg N	40+40+40 Fu	40+40+60Fu	40+40+40Fu + Strob
Expression	200	4.98	4.92	4.98	5.34	5.37
	400	5.02	5.07	5.36	5.36	5.14
Expression Total		5.00	5.00	5.17	5.35	5.26
Grafton	200	5.71	5.84	5.76	5.47	5.68
	400	5.82	6.41	5.96	6.22	6.36
Grafton Total		5.77	6.13	5.86	5.84	6.02
Hendon	200	6.86	6.82	6.62	6.48	6.41
	400	6.60	6.97	6.28	6.88	7.05
Hendon Total		6.73	6.90	6.45	6.68	6.73
Grand Total		5.72	5.90	5.75	5.87	5.91
Variety p value		**<0.001**				
SED		**0.096**				
Seed rate p value		**0.007**				
SED		**0.078**				
Nit/Fung p value		**NS**				
SED		**0.123**				
Var x Srate p value		**NS**				
SED		**0.135**				
Var x Nit/Fung p value		**NS**				
SED		**0.214**				
Srate x Nit/Fung p value		**NS**				
SED		**0.175**				
Var x Srate x Nit/Fung p value		**NS**				
SED		**0.302**				
df		**48**				
cv%		**6.2**				

Table 50. Whole plot lodging assessments

Lodging		Nit/Fung Treatment				
Variety	Seedrate	120 kgN	40+80 kg N	40+40+40 Fu	40+40+60Fu	40+40+40Fu + Strob
Expression	200	58.33	71.67	15.00	8.33	25.00
	400	76.67	55.00	3.33	16.67	16.67
Expression Total		67.50	63.33	9.17	12.50	20.83
Grafton	200	41.67	20.00	0.00	0.00	0.00
	400	20.00	16.67	0.00	0.00	0.00
Grafton Total		30.83	18.33	0.00	0.00	0.00
Hendon	200	0.00	0.00	0.00	0.00	0.00
	400	0.00	0.00	0.00	0.00	0.00
Hendon Total		0.00	0.00	0.00	0.00	0.00
Grand Total		36.88	30.63	3.44	4.69	7.81
Variety p value		**<0.001**				
SED		**5.00**				
Seed rate p value		**NS**				
SED		**4.08**				
Nit/Fung p value		**<0.001**				
SED		**6.46**				
Var x Srate p value		**NS**				
SED		**7.07**				
Var x Nit/Fung p value		**0.004**				
SED		**11.18**				
Srate x Nit/Fung p value		**NS**				
SED		**9.13**				
Var x Srate x Nit/Fung p value		**NS**				
SED		**15.82**				
df		**48**				
cv%		**139.2**				

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Table 51. Autumn plant populations

Nitrogen	Variety	Plants/m^2
100 kg/ha N	Hendon	343.7
	Buffalo	330.7
	Millennium	326.9
100 kg/ha N	Mean	333.8
160 kg/ha N	Hendon	355.6
	Buffalo	319.3
	Millennium	299.0
160 kg/ha N	Mean	324.6
190 kg/ha N	Hendon	360.6
	Buffalo	377.4
	Millennium	346.7
190 kg/ha N	Mean	361.5
Hendon	Mean	342.5
Buffalo	Mean	353.3
Millennium	Mean	324.2
Overall	Mean	340.0
CV%		**4.4**
Nitrogen SED		**10.64**
p value		**0.031**
DF		**6**
Variety SED		**13.06**
P value		**NS**
CV%		**9.4**
Interaction SED		**21.32**
P value		**NS**
DF		**13**

Figure x. Percentage Photosynthetic Active Radiation absorbed by the crop in three nitrogen treatments mean of three varieties.

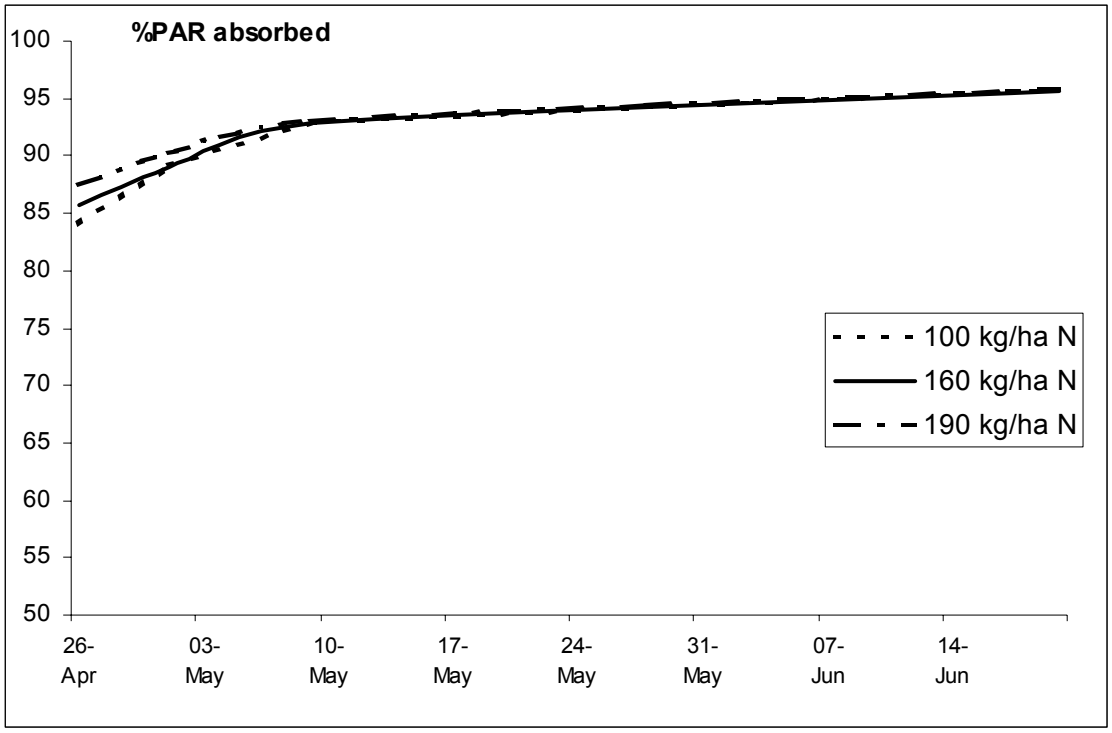

Table 52. Pre-harvest Biomass, Crop dry matter t/ha

Nitrogen	Variety	Straw	Grain	Chaff	Total
100 kg/ha N	Hendon	7.57	6.25	3.41	17.24
	Buffalo	5.98	5.68	3.02	14.69
	Millennium	6.73	6.96	2.05	15.74
100 kg/ha N	Mean	6.76	6.30	2.83	15.89
160 kg/ha N	Hendon	7.34	6.54	3.45	17.32
	Buffalo	7.72	8.32	2.08	18.13
	Millennium	7.90	7.88	1.89	17.67
160 kg/ha N	Mean	7.68	7.68	2.38	17.74
190 kg/ha N	Hendon	7.68	7.00	3.23	17.91
	Buffalo	7.48	7.48	1.69	16.66
	Millennium	5.56	4.58	1.57	11.71
190 kg/ha N	Mean	6.91	6.36	2.16	15.43
Hendon	Mean	7.53	6.60	3.36	17.49
Buffalo	Mean	7.06	7.16	2.27	16.49
Millennium	Mean	6.73	6.48	1.84	15.04
Overall	Mean	7.10	6.75	2.46	16.31
CV%		**19.5**	**10.2**	**29.9**	**13.9**
Nitrogen SED		**0.983**	**0.486**	**0.533**	**1.608**
p value		**NS**	**0.071**	**NS**	**NS**
DF		**6**	**6**	**6**	**6**
Variety SED		**0.520**	**0.912**	**0.543**	**1.538**
p value		**NS**	**NS**	**0.023**	**NS**
CV%		**17.8**	**33.2**	**52.8**	**23.0**
Interaction SED		**1.227**	**1.378**	**0.934**	**2.705**
p value		**NS**	**NS**	**NS**	**NS**
DF		**17**	**17**	**17**	**17**

Table 53. Pre-harvest Biomass, Yield components

Nitrogen	Variety	Harvest Index	Thousand grain weight g @ 85%	Grain weight /ear	Grain number /ear	Ear number /m^2
100 kg/ha N	Hendon	36.53	20.51	1.12	62.83	572.60
	Buffalo	40.78	28.84	1.83	71.97	329.11
	Millennium	44.38	37.19	1.28	39.17	556.05
100 kg/ha N	Mean	40.56	28.85	1.41	57.99	485.92
160 kg/ha N	Hendon	37.94	20.12	1.17	66.86	566.07
	Buffalo	46.09	29.94	2.05	78.87	408.02
	Millennium	42.77	35.30	1.12	35.17	690.29
160 kg/ha N	Mean	42.66	29.21	1.47	59.70	553.77
190 kg/ha N	Hendon	38.92	20.58	1.16	65.19	602.93
	Buffalo	45.04	28.65	2.13	85.21	361.02
	Millennium	38.45	31.98	0.88	30.71	545.61
190 kg/ha N	Mean	40.80	27.07	1.39	60.37	503.19
Hendon	Mean	37.80	20.40	1.15	64.96	580.53
Buffalo	Mean	43.97	29.14	2.00	78.68	366.05
Millennium	Mean	41.86	34.82	1.10	35.02	597.32
Overall	Mean	41.30	28.35	1.42	59.34	513.16
CV%		**10.8**	**10.4**	**11.0**	**16.4**	**8.9**
Nitrogen SED		**3.12**	**2.070**	**4.60**	**0.164**	**32.3**
p value		**NS**	**NS**	**NS**	**NS**	**NS**
DF		**6**	**6**	**6**	**6**	**6**
Variety SED		**2.87**	**1.964**	**5.90**	**0.182**	**32.8**
p value		**NS**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
CV%		**17.1**	**17.1**	**24.3**	**31.6**	**15.6**
Interaction SED		**5.12**	**3.464**	**9.53**	**0.305**	**56.5**
p value		**NS**	**NS**	**NS**	**NS**	**NS**
DF		**17**	**17**	**17**	**17**	**17**

Table 54. Yield data

Nitrogen	Variety	Grain yield t/ha	Specific weight kg/hl	Thousand grain weight g
100 kg/ha N	Hendon	6.37	57.37	20.43
	Buffalo	9.13	51.64	33.64
	Millennium	9.20	51.17	41.76
100 kg/ha N	Mean	8.23	53.39	31.95
160 kg/ha N	Hendon	6.85	56.49	23.36
	Buffalo	9.10	48.23	34.59
	Millennium	8.99	51.93	41.21
160 kg/ha N	Mean	8.45	52.22	33.05
190 kg/ha N	Hendon	6.17	59.63	19.64
	Buffalo	8.97	48.99	33.42
	Millennium	9.25	51.69	41.28
190 kg/ha N	Mean	8.13	53.44	31.44
Hendon	Mean	6.46	57.83	21.14
Buffalo	Mean	9.07	49.62	33.88
Millennium	Mean	9.15	51.60	41.42
Overall	Mean	8.27	53.02	32.15
CV%		**2.6**	**2.9**	**4.5**
Nitrogen SED		**0.153**	**1.074**	**1.027**
p value		**NS**	**NS**	**NS**
DF		**6**	**6**	**6**
Variety SED		**0.225**	**1.045**	**1.110**
p value		**<0.001**	**<0.001**	**<0.001**
CV%		**6.7**	**4.8**	**8.5**
Interaction SED		**0.353**	**1.827**	**1.876**
p value		**NS**	**NS**	**NS**
DF		**17**	**18**	**18**

Table 55. Whole plot lodging assessments

		Lodging assessments %		
Nitrogen	Variety	20th June	17th July	29th July
100 kg/ha N	Hendon	0.00	2.50	37.50
	Buffalo	0.00	0.00	8.75
	Millennium	12.50	33.75	31.25
100 kg/ha N	Mean	4.17	12.08	25.83
160 kg/ha N	Hendon	0.00	0.00	43.75
	Buffalo	0.00	0.00	17.50
	Millennium	26.25	57.50	51.25
160 kg/ha N	Mean	8.75	19.17	37.50
190 kg/ha N	Hendon	0.00	11.25	62.50
	Buffalo	0.00	0.00	36.25
	Millennium	46.25	72.50	68.75
190 kg/ha N	Mean	15.42	27.92	55.83
Hendon	Mean	0.00	4.58	47.92
Buffalo	Mean	0.00	0.00	20.83
Millennium	Mean	28.33	54.58	50.42
Overall	Mean	9.44	19.72	39.72
CV%		**51.9**	**25.7**	**35.3**
Nitrogen SED		**3.46**	**3.58**	**9.91**
p value		**0.047**	**0.013**	**0.060**
DF		**6**	**6**	**6**
Variety SED		**3.30**	**4.17**	**6.58**
p value		**<0.001**	**<0.001**	**<0.001**
CV%		**85.5**	**51.7**	**40.6**
Interaction SED		**5.81**	**6.90**	**13.59**
p value		**0.003**	**0.012**	**NS**
DF		**18**	**18**	**18**

Nitrogen x Variety trial

SW Abbots Ripton site

Table 56. Yield t/ha @ 85% dry matter

Nitrogen	Variety	Grain yield t/ha
100 kg/ha N	Hendon	4.17
	Buffalo	6.26
	Millennium	7.26
100 kg/ha N	Mean	5.90
130 kg/ha AN	Hendon	4.78
	Buffalo	6.15
	Millennium	7.67
130 kg/ha AN	Mean	6.20
130 kg/ha AN + 30 kg FU	Hendon	5.16
	Buffalo	7.58
	Millennium	8.56
130 kg/ha AN + 30 kg FU	Mean	7.10
130 kg/ha AN + 30 kg Late AN	Hendon	5.22
	Buffalo	8.21
	Millennium	8.71
130 kg/ha AN + 30 kg Late AN	Mean	7.38
160 kg/ha N	Hendon	4.99
	Buffalo	8.16
	Millennium	9.63
160 kg/ha N	Mean	7.59
190 kg/ha N	Hendon	5.12
	Buffalo	8.43
	Millennium	8.86
190 kg/ha N	Mean	7.47
Hendon	Mean	4.91
Buffalo	Mean	7.46
Millennium	Mean	8.45
Overall	Mean	6.94
CV%		**7.8**
Nitrogen SED		**0.306**
p value		**<0.001**
DF		**10**
Variety SED		**0.180**
p value		**<0.001**
Interaction SED		**0.473**
p value		**0.085**
DF		**24**