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Nitrogen management in spring malting barley for optimum yield and quality

by

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Contents

Abstract

A series of trials investigated the agronomy of spring malting barley grown with high levels of applied nitrogen (150-200 kg/ha N). Growth regulators, seed rates and number of nitrogen applications (splits), and their influence on nitrogen dose response, were examined in trials run at four sites in England and one in Scotland. The trials were conducted over three years, 2002-2004, with varieties Optic and Cellar.
In most trials the yield response to nitrogen rates between 150 kg/ha and 200 kg/ha was fairly flat. Higher rates frequently produced excessive grain nitrogen and the optimum rate was usually 150 kg/ha, particularly for Cellar. In the Hampshire trial in particular, Optic occasionally maintained grain N in the target range (1.65-1.85%) with 175 kg/ha.

Growth regulators were rarely required for lodging control, lodging being infrequent throughout the trial series. In 2002, fertile tiller numbers were unusually high at some of the trial sites, which led to a high proportion of small grains and hence high screening levels. A sequence of Moddus followed by Terpal prevented excessive tiller numbers, thereby reducing screenings. However, this effect was most consistent with higher rates of applied N (e.g. 175 and 200 kg/ha), which tended to produce excessive grain nitrogen, a parameter which was not influenced by growth regulators in this case. At the more appropriate 150 kg/ha level these growth regulator effects were less consistent. These effects were also not seen in 2003 and 2004, when excessive screenings were not a significant problem.

Despite this, small yield increases seen with a single Terpal treatment (rather than the Moddus/Terpal sequence) were sufficient to make this treatment cost-effective at two of three sites.

Seed rate studies looking at 200, 300 and 400 seeds/m^2 indicated that occasionally 200, but more often 300 seeds were adequate, with either a low (100 kg/ha) or a high (175 kg/ha) rate of applied nitrogen. High grain nitrogen levels seen with the higher applied nitrogen rate were reduced with the higher seed rates, particularly where growth regulators were used, but these effects were small.

Splitting the applied nitrogen, i.e. applying it in more than one dose, was beneficial to yield and grain quality with the higher rates of N, but again 150 kg/ha was a safer rate in terms of optimum yield and reliability of keeping grain nitrogen in the required range. At this rate of applied N, there was no disadvantage in applying a single dose at early crop emergence.

Summary report

Introduction

In recent years, changes in the market requirements for spring malting barley have led to a change in the agronomy of the crop. In particular, the preference for grain nitrogen levels higher than traditionally aimed for, specifically for the export market, has led to the use of higher rates of nitrogen fertiliser in order to achieve the required quality parameters. As with all crops, increased rates of nitrogen have profound effects on the crop in terms of growth and consequent agronomic management.

This project specifically addressed the husbandry requirements of spring malting barley grown under these higher nitrogen regimes, with reference to:

a) total nitrogen dose,
b) optimum seed rate,
c) nitrogen timing, and
d) response to plant growth regulators.

The effect on yield and grain quality of all these agronomic factors was assessed, with the aim of producing guidelines for the grower of malting spring barley for the export market.

Methods

The project consisted of three trial series, namely:

1. Interaction of nitrogen rate and plant growth regulator (PGR) input.

Four rates of nitrogen (100, 150, 175, & 200 kg N/ha) were applied to each of two varieties, Optic and Cellar. Superimposed across the nitrogen treatments were three PGR programmes (untreated, a single Terpal spray, and a Moddus/Terpal* sequence respectively). The nitrogen dose response, for grain yield and grain quality, was then produced for each PGR programme.

This trial was conducted at three sites, Perth, Andover (Hants) and Morley (Norfolk).

* Terpal contains 2-chloroethylphosphonic acid + mepiquat chloride. Moddus contains trinexapac-ethyl

2. Interaction between seed rate, nitrogen rate and PGR input.

Two varieties, Optic and Cellar, were sown at each of three seed rates (200, 300 & 400 seeds/m^2). Each of these was then treated with two nitrogen programmes (100 and 175 kgN/ha respectively), and two PGR programmes (no treatment, and a Moddus/Terpal sequence). This trial was conducted at Perth, Grantham and Cirencester, Gloucestershire.

3. Nitrogen timing and dose in the presence of a PGR programme.

This trial series looked at ways of delivering higher rates of nitrogen fertiliser. Four total N rates (100, 150, 175 and 200 kg/ha) were applied in a single dose, two splits or three splits respectively. All

combinations were then treated with one of two PGR treatments (untreated, and a Moddus/Terpal sequence).
This trial was carried out at three sites, Perth, Andover and Morley.

Results

1. Nitrogen dose and growth regulator response

Table 1. Yields (t/ha) – three year means for Optic and Cellar, at Andover, Morley and Perth.

N (kg/ha)	PGR	Optic			Cellar		
		Andover	**Morley**	**Perth**	**Andover**	**Morley**	**Perth**
100	-	6.01	6.51	6.76	6.06	6.42	7.16
150	-	6.76	6.70	6.96	6.75	6.85	7.41
175	-	6.87	6.90	6.64	6.98	6.81	7.82
200	-	7.00	6.69	6.85	7.03	6.87	7.75
100	Terpal	6.10	6.66	6.77	5.94	6.55	7.00
150	Terpal	6.76	7.01	7.15	6.81	7.18	7.33
175	Terpal	6.95	6.84	6.90	6.93	7.14	7.30
200	Terpal	7.09	7.02	6.87	7.29	7.07	7.53
100	Moddus/Terpal	6.13	6.80	6.62	5.97	6.88	6.70
150	Moddus/Terpal	6.67	6.95	7.05	6.90	6.84	7.47
175	Moddus/Terpal	7.07	7.06	6.94	6.72	7.02	7.65
200	Moddus/Terpal	7.24	6.87	7.23	7.06	7.24	7.62

PGR treatments:
(i) Terpal 0.5 l/ha GS39-45
(ii) Moddus (0.2 l/ha) GS30, followed by Terpal (0.5 l/ha) GS39-45.

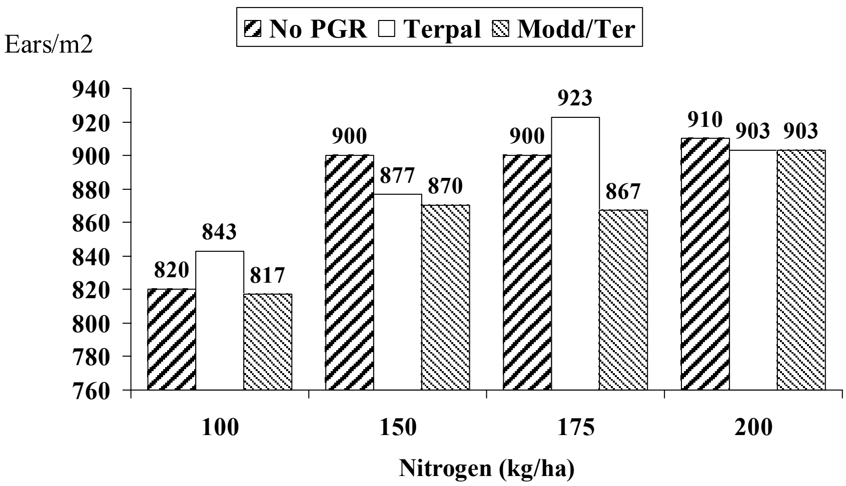
In the Andover trials, Optic gave its optimum yield with the highest N rate applied (200 kg/ha), whilst Cellar tended to peak around 150-175 kg/ha. Both the Morley and Perth trials tended to produce flatter nitrogen responses for both varieties, with highest yields again resulting from 150, and occasionally 175, kg/ha. There are no consistent effects of either growth regulator treatment on yield, when each respective N rate is considered.

Table 2. Grain nitrogen content (%) – Optic and Cellar; three-year means (Perth), two-year means (Andover, Morley*).

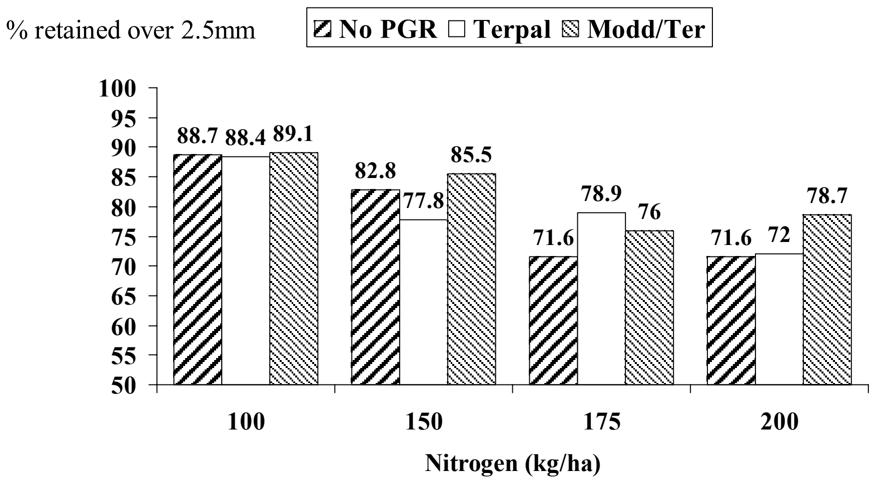
N (kg/ha)	PGR	Optic			Cellar		
		Andover	**Morley**	**Perth**	**Andover**	**Morley**	**Perth**
100	-	1.57	1.54	1.50	1.64	1.64	1.62
150	-	1.72	1.78	1.75	1.74	1.81	1.79
175	-	1.84	1.92	1.89	1.83	1.95	1.90
200	-	1.90	1.97	1.96	1.94	1.99	2.00
100	Terpal	1.62	1.54	1.56	1.65	1.59	1.63
150	Terpal	1.67	1.79	1.82	1.71	1.85	1.78
175	Terpal	1.78	1.87	1.84	1.81	1.89	1.86
200	Terpal	1.86	1.95	1.98	1.91	1.99	2.00
100	Moddus/Terpal	1.57	1.54	1.52	1.61	1.63	1.59
150	Moddus/Terpal	1.70	1.77	1.75	1.68	1.80	1.82
175	Moddus/Terpal	1.72	1.87	1.85	1.77	1.91	1.88
200	Moddus/Terpal	1.85	1.92	1.92	1.89	1.91	2.00

*Grain N values for Andover in 2004 were very low, with a maximum of 1.67% across all N treatments. In the Morley trial in 2004, yields were fairly low and hence all grain N values were high (above 2.00% even with 100 kg/ha N). Therefore these datasets have been omitted from the means.

With a target grain N range of 1.65-1.85% assumed for this project, the optimum applied N rate for both Optic and Cellar at Andover would have been 175 kg/ha, despite the higher yields seen with 200 kg/ha (see above). In both the Morley and Perth trials, the 'safest' N rate was 150 kg/ha, though 175 kg/ha on Optic just fell in the required range. In addition, there is evidence that the growth regulator programmes reduced grain N slightly, bringing certain treatments back into the target range, though these increases were fairly small and were never statistically significant in the original data. Therefore, although the spring barley in these trials occasionally gave yield responses up to 200 kg/ha applied N, taking grain quality into account the optimum N rate was 150 kg/ha for Cellar, and 175 kg/ha for Optic. These N rates were also the optimum for yield at Morley and Perth in particular. There was little or no evidence of an influence from growth regulators on these optimum nitrogen rates. However, in 2002 the growth regulator programmes did influence grain quality as measured by screenings (grain retention over a 2.5mm sieve). In that year growing conditions resulted in high ear numbers, which increased the screenings in the sample, i.e. reduced the sieve retention. This effect was illustrated well in the Perth trial:



Ear numbers exceeded $900/m^2$, but the Moddus/Terpal sequence in particular reduced them except at the highest N rate.



LSD 5.2%

As nitrogen rate was increased, grain retention decreased to well below the 90% target, but there are indications that the moderation of ear numbers seen with the growth regulator treatments led to better grain retention. This effect, which was seen to a lesser degree at the other sites in 2002, was not seen in 2003 or 2004, when ear numbers were more typical and screenings closer to the target levels.

Cost benefit analysis

The following table gives the net margins for the three trials in this series, based on three-year mean data for each site, for Optic only. For this exercise, the lowest input (100 kg/ha N, no growth regulator) is taken as the control, with the margins from other treatments based on their yield over and above that of this control treatment.

The grain prices assumed are:

£72/tonne for 1.65-1.85% grain N, and a minimum 90% retention over a 2.5mm sieve.

£60/tonne for any sample outside either of these specifications.

In reality there may still be discounted premiums for figures just outside these specifications, but as these are difficult to define they have not been allowed for here.

Nitrogen applied (kg/ha)	PGR	Net margin (£/ha)		
		Andover	Morley	Perth
100	-	0	0	0
150	-	33	11	-7
175	-	30	-1	-39
200	-	16	-27	-37
100	Terpal	1	7	-3
150	Terpal	29	20	3
175	Terpal	32	-13	-26
200	Terpal	18	-15	-39
100	Moddus/Terpal	-3	12	-18
150	Moddus/Terpal	16	9	-10
175	Moddus/Terpal	34	3	-29
200	Moddus/Terpal	36	-22	-24

Generally the most cost-effective nitrogen rate was 150 kg/ha. The figures for Andover indicate slightly higher margins with 175 and 200 kg/ha where the PGR sequence was used, but the differences are small and it could be argued they would not pay for the application costs of two PGR timings (application costs not included in these calculations). At Morley and Perth 150 kg/ha was also the most cost-effective, but in both cases this was so where a single PGR treatment (Terpal) was applied, and here the differences are likely to cover application costs. However, in the Perth trials this was the only treatment to generate a positive margin, mainly because the yields of the control treatment were relatively high at this site, but, again allowing for application costs, the control treatment (100 kg/ha N with no PGR) was effectively the most cost-effective (and would have been more so if the intended market was for a grain nitrogen level below 1.65%, which may be the case in Scotland).

Therefore, with the exception of the Terpal-only treatment at Morley, there is argument to apply growth regulator treatment, or for total N rates above 150 kg/ha.

Trial 2. Seed rate - interaction with growth regulators and nitrogen rate

Table 3. Yield (t/ha), Optic and Cellar; three-year means, Cirencester, Caythorpe and Perth.

Nitrogen (kg/ha)	Seed rate (/m^2)	PGR	Optic			Cellar		
			Cirencester	Caythorpe	Perth	Cirencester	Caythorpe	Perth
100	200	-	6.18	6.36	6.41	6.19	6.17	6.86
100	200	+	6.30	6.24	6.61	6.00	6.37	6.71
100	300	-	6.43	6.50	6.71	6.55	6.33	6.84
100	300	+	6.52	6.52	6.78	6.54	6.60	6.68
100	400	-	6.53	6.20	6.57	6.33	6.20	6.68
100	400	+	6.74	6.33	6.72	6.26	6.65	6.98
175	200	-	6.43	6.54	6.85	6.63	6.52	7.47
175	200	+	6.34	6.52	6.99	6.63	6.72	7.47
175	300	-	6.73	6.56	6.98	6.86	6.67	7.60
175	300	+	6.83	6.77	7.03	6.92	7.00	7.67
175	400	-	6.94	6.53	6.81	6.95	6.75	7.63
175	400	+	7.12	7.00	7.12	6.87	7.01	7.54

PGR – Moddus (0.2 l/ha) GS30, followed by Terpal (0.5 l/ha) GS39-45.

In most cases the optimum yields were achieved with 300 seeds/m^2, with 200 being sufficient in one or two cases (e.g. Perth, Cellar, 175 kg/ha N, and Caythorpe, Optic, 100 kg/ha N). Responses to the highest rate (400) are only seen with the inclusion of the PGR treatment, and then predominantly with the higher N rate. Therefore, with the highest inputs, the PGR treatment appeared to increase yield, but with other treatment combinations the responses to PGR were inconsistent.

Table 4. Grain nitrogen content (%) Optic and Cellar; three-year means, Cirencester, Caythorpe and Perth.

Nitrogen (kg/ha)	Seed rate (/m^2)	PGR	Optic			Cellar		
			Cirencester	Caythorpe	Perth	Cirencester	Caythorpe	Perth
100	200	-	1.68	1.73	1.52	1.72	1.68	1.66
100	200	+	1.75	1.67	1.57	1.74	1.69	1.62
100	300	-	1.64	1.66	1.46	1.70	1.68	1.58
100	300	+	1.64	1.74	1.50	1.67	1.67	1.60
100	400	-	1.67	1.62	1.51	1.64	1.71	1.58
100	400	+	1.63	1.72	1.55	1.64	1.70	1.56
175	200	-	2.05	1.94	1.88	2.03	1.93	1.97
175	200	+	2.02	1.85	1.86	2.01	1.92	1.96
175	300	-	1.97	1.87	1.83	1.98	1.87	1.94
175	300	+	1.99	1.86	1.85	1.99	1.90	1.88
175	400	-	1.93	1.88	1.80	1.90	1.88	1.90
175	400	+	1.93	1.85	1.81	1.94	1.90	1.95

Not surprisingly, the applied nitrogen level is the over-riding factor, with 175 kg/ha N producing excessive grain N at Cirencester and Caythorpe in both varieties, and at Perth in Cellar. Higher seed rates had small effects in reducing grain N, particularly where 175 kg was applied, but only in one case (Optic at Perth) was this sufficient to bring the grain N back into the target range. Growth regulator use had little or no effect on grain nitrogen, for each comparable treatment.

3. Nitrogen timing and dose.

Table 5. Yield (t/ha), three-year means, Andover, Morley and Perth. cv Optic.

Nitrogen (kg/ha)	No. splits	PGR	Andover	Morley	Perth
100	1	-	6.48	6.83	6.37
100	2	-	6.45	6.89	6.75
100	3	-	6.07	6.73	6.36
100	1	+	6.35	7.02	6.72
100	2	+	6.45	6.96	6.92
100	3	+	6.22	6.98	7.12
150	1	-	7.02	6.93	7.28
150	2	-	7.02	7.01	7.17
150	3	-	6.73	6.95	7.20
150	1	+	7.15	7.10	7.30
150	2	+	7.11	7.17	7.46
150	3	+	6.90	7.27	7.68
175	1	-	6.93	6.93	7.25
175	2	-	7.16	6.98	7.33
175	3	-	6.96	6.99	7.38
175	1	+	7.03	7.18	7.40
175	2	+	7.36	7.15	7.46
175	3	+	7.22	7.29	7.62
200	1	-	7.29	6.79	7.09
200	2	-	7.25	6.94	7.58
200	3	-	7.21	6.77	7.48
200	1	+	7.49	7.02	7.18
200	2	+	7.38	7.22	7.63
200	3	+	7.45	7.23	7.37

PGR – Moddus (0.2 l/ha) GS30, followed by Terpal (0.5 l/ha) GS39-45.

N timings: 1 split: all applied at GS11. 2-split: 50% seedbed & GS11. 3-split: 1/3 seedbed, 1/3 GS11, 1/3 GS23-30.

In the Perth trial, there were yield responses to splitting 200 kg/ha either two or three ways, with or without a growth regulator. In other trials, and with lower nitrogen rates, there was little or no benefit to splitting the total nitrogen and even with 200 kg/ha there was rarely a penalty from applying all in a single dose at the one-leaf stage (GS11). In addition, there were occasionally yield penalties when the lowest N rate, 100 kg/ha, was applied in more than one application.

Table 6. Grain nitrogen content (%), three-year means, Andover, Perth and two-year mean for Morley. cv Optic.

Nitrogen (kg/ha)	No. splits	PGR	Andover	Morley	Perth
100	1	-	1.66	1.66	1.59
100	2	-	1.56	1.55	1.56
100	3	-	1.63	1.58	1.51
100	1	+	1.61	1.63	1.55
100	2	+	1.60	1.59	1.47
100	3	+	1.60	1.60	1.54
150	1	-	1.68	1.90	1.73
150	2	-	1.68	1.82	1.71
150	3	-	1.66	1.89	1.74
150	1	+	1.69	1.86	1.76
150	2	+	1.66	1.80	1.70
150	3	+	1.67	1.85	1.71
175	1	-	1.83	2.02	1.90
175	2	-	1.73	1.94	1.80
175	3	-	1.73	1.94	1.75
175	1	+	1.85	1.92	1.88
175	2	+	1.73	1.88	1.80
175	3	+	1.69	1.79	1.82
200	1	-	1.82	2.09	1.91
200	2	-	1.85	1.98	1.85
200	3	-	1.75	2.04	1.89
200	1	+	1.90	2.07	1.99
200	2	+	1.80	1.98	1.87
200	3	+	1.81	2.02	1.87

At Morley, any applied N rate above 150 kg/ha frequently produced grain N above 1.85%, whilst at Perth the same occurred with 200 kg/ha only. In the Andover trials, grain N levels were below 1.85 % with 175 kg/ha applied N, and also with 200 kg/ha provided PGR was not used, which in this case raised grain N slightly. Otherwise there were no consistent effects of growth regulator on grain nitrogen.

In the Andover trial, splitting the nitrogen reduced the grain N with total applied N rates of 175 and 200 kg/ha. Similar trends were seen at Morley and Perth but they were less consistent than those at Andover.

Conclusions

The main concern with the higher nitrogen rates being applied to spring barley was the possibility that growth regulators would become routine inputs, when they had been very rarely used in this crop beforehand. In all three of the trials in this project, growth regulators had only marginal effects. Lodging was not consistently seen at significant levels in any of the trials, and usually only with applied nitrogen rates up to 200 kg/ha. At such a nitrogen rate, the grain nitrogen level was usually excessive.

One benefit seen from the use of growth regulators, however, was a 'moderation' of fertile tiller numbers in 2002, particularly with the PGR sequence including Moddus applied at GS30. A common effect seen in that year was the high fertile ear number, which was encouraged by late uptake of nitrogen. Where Moddus had been applied, the fertile tiller number was reduced; this in turn reduced the number of small grains (screenings) in the sample. Whilst the high fertile tiller numbers did not influence yield or grain nitrogen content, the high screenings may have affected the marketability of the grain, and hence in this case the growth regulator would have had a financial benefit. However, another consistent result in these trials was the optimum rate of applied nitrogen for yield and grain nitrogen level, which was in most cases 150 kg/ha N. At this rate, the high fertile tiller number and screenings were less of a problem, which again, therefore, questions the value of growth regulator programmes. In addition, these effects were not seen in 2003 or 2004 when tillering patterns were more typical. Nevertheless, this may indicate a role for an early-season growth regulator where, for example, tiller numbers are exceptionally high.

Seed rates also had little effect on yield or quality. Of the rates tested, 200/ seeds/m^2 (the lowest) was occasionally sufficient, though more commonly 300 seeds/m^2 were needed (giving plant populations around 200 plants/m^2). Yield was occasionally improved with 400 seeds/^{2}, provided a growth regulator programme was applied and a higher (175 kg/ha) nitrogen rate applied, but this still did not out-perform the lower seed rates without growth regulator treatment. Seed rate had some influence on grain quality, in terms of grain nitrogen content, with higher seed rates slightly reducing grain nitrogen, but again this was only seen with the higher rate of applied nitrogen. This might indicate a benefit from higher seed rates in moderating grain nitrogen content where this might be expected to be high, but this in turn would be allowed for with the rate of nitrogen applied, rather than earlier with the seed rate decision.

Finally, the need to split the nitrogen into more than one application was also addressed, and with the higher rates of N (175 and 200 kg/ha) there were occasional benefits in splitting the application. However, at the levels of applied nitrogen which were optimum for yield and grain quality (again 150 kg/ha), there was no benefit in applying the N as more than a single dose at early crop emergence.

Overall, this project indicated that where rates of applied nitrogen need to be raised above traditional levels in response to market demands, significant changes in agronomy as a result were not necessary.

Technical Report

Introduction

Malting barley has long been an important crop in the UK, and the more recent development of overseas markets have further increased its significance, with latest export figures showing over 397,000 tonnes of malt barley exported in 2003/4 (source: HGCA). Clearly it is important for the product to match the specific requirements of these markets, and the dominance of lager-type beers on the Continent, and their growing popularity in the UK, has led to UK market requirements shifting towards the production of grain suitable for lager production. In practice this means aiming for a higher grain nitrogen level than has been the traditional target, and the 2005 'wish list' from UK maltsters indicates that of their intended purchases of spring barley, 54% of the English crop, and 14% of the Scottish crop, will be in the grain nitrogen range 1.65-1.85%. (MAGB, 2005). Whilst the market has recently shown a slight shift away from these higher grain N samples (the same figure for 2004 was 64%), the majority of the spring malting barley crop in England still requires a higher grain N level than has traditionally been targeted.

In this report, the target grain N for the various experimental treatments is therefore taken as 1.65-1.85% (referred to as the 'target range'). In Scotland, there is still a significant market for lower grain N of 1.65% or lower, and the intended purchase figures for Scotland indicate that 77% of the spring barley bought in 2005 will have grain N below 1.65%. This will be taken into account when the trials at Perth are discussed.

To achieve the higher target of 1.65-1.85%, the nitrogen fertiliser agronomy of the crop has had to be re-addressed. To achieve a higher level of nitrogen in the grain, growers need simply to apply more nitrogen fertiliser. However, other agronomic measures can also influence grain quality. Since their introduction, strobilurin fungicides have given the same yield benefits to spring barley as to other cereal crops, and their ability to increase yield without the use of nitrogen fertiliser, has created a trend towards lower grain nitrogen levels, through 'grain N dilution'. To counteract this, and to bring the grain nitrogen back up to the level required, even more nitrogen fertiliser may need to be applied.
An earlier HGCA-funded project, 'Effect on yield and quality of strobilurin applications to spring malting barley' report no. 250 (Overthrow), showed that the use of strobilurin-based fungicide programmes in conjunction with traditional nitrogen fertiliser rates (e.g. 100-125 kg N/ha) consistently produced grain with nitrogen levels well below the market requirements, and these could only be met with total rates of 150 kg N/ha or more.

Whilst these higher nitrogen rates will produce higher yields along with the optimum grain quality, they will also have an impact on other aspects of the crop's agronomy, not least how the nitrogen should be delivered, the lower rates traditionally used often being applied in a single dose. Also, for most growers, lodging has not been a regular problem in spring barley, but these higher N rates may create a requirement for plant growth regulators, which themselves may have an influence on yield and quality. The effects of nitrogen will also be influenced by plant population, and seed rates themselves may influence the standing ability of the crop and therefore its need for growth regulators. Seed rate has also been shown to influence grain quality in spring barley, earlier HGCA-funded work (Wade & Muller, report 320 vol 1&2) demonstrating an increase in grain nitrogen level as seed rate, and subsequent plant population, increased. In the same project it was shown that yield levelled out at 200 seeds/m^2 (when the seed rate was increased from 50 to 800 seeds.m^2).

All of these issues suggest the need for a re-appraisal of spring malting barley agronomy, grown under higher nitrogen fertiliser regimes for the export market in particular. This project looked at the agronomic factors discussed above, and the interactions between a number of inputs, with a view to producing such husbandry guidelines.

The project consisted of three separate trial protocols, each conducted at several locations in the UK. The three trials are presented separately in this report.

Trial 1. Interaction of nitrogen rate and plant growth regulator (PGR) input.

Materials and methods

Trial plots of two spring barley varieties, Optic and Cellar, were sown in spring at each of three locations, Perth, Andover (Hants) and Morley (Norfolk). Each variety was subjected to a number of total nitrogen (N) rates, with three plant growth regulator (PGR) treatments superimposed, as follows:

N:

100, 150, 175, 200 kg N/ha. All applied in two applications, 50% pre-emergence and 50% at two-three leaf (GS12-13).

PGR:

a) No PGR

b) Terpal (2-chloroethylphosphonic acid + mepiquat) at 0.5 l/ha, applied between GS39-49

c) Moddus (trinexapac-ethyl) at 0.2 l/ha, applied at GS30, followed by Terpal as above.

This produced a series of nitrogen response curves, for yield and grain quality, for each PGR programme.

Trial sites

1. Stanley, near Perth. Light sandy loam
2. Andover, Hants. Shallow soil over limestone chalk, 343h (Andover 1 series)
3. Morley, Norfolk. Sandy loam over chalky boulder clay, 572q (Ashley series)

All trials were sown at seed rates suitable for the location, and grown according to typical local husbandry. However, all disease control programmes involved two strobilurin-based sprays.

Trials were assessed for fertile tiller (ear) number, grain yield, grain nitrogen content and screenings.

The trials were conducted in 2002, 2003 and 2004.

Results

1. Andover

Table 1. Yields (t/ha) – cv Optic

N (kg/ha)	PGR	2002	2003	2004	3-year mean
100	-	5.46	6.88	5.69	6.01
150	-	5.87	7.50	6.91	6.76
175	-	5.73	7.69	7.19	6.87
200	-	5.47	8.00	7.52	7.00
100	Terpal	5.84	6.70	5.76	6.10
150	Terpal	5.61	7.69	6.99	6.76
175	Terpal	6.08	7.51	7.25	6.95
200	Terpal	5.79	8.04	7.43	7.09
100	Moddus/Ter	5.65	7.14	5.59	6.13
150	Moddus/Ter	5.67	7.62	6.73	6.67
175	Moddus/Ter	6.00	8.07	7.14	7.07
200	Moddus/Ter	6.01	8.15	7.56	7.24
LSD (0.05)		*0.42*	*0.46*	*0.91*	

In 2003 and 2004, the yields increased as applied nitrogen dose increased, though the highest yields achieved were not influenced by PGR treatment, and for each dose of applied N, there were no significant differences between the PGR treatments. In 2002 the yields for all three PGR programmes peaked at 175 kg/ha applied N, and whilst the differences were not statistically significant, the PGR programmes did consistently give higher yields than the untreated (PGR) control.

Table 2. Yields (t/ha) – cv Cellar

N (kg/ha)	PGR	2002	2003	2004	3-year mean
100	-	6.01	6.59	5.58	6.06
150	-	6.52	7.20	6.52	6.75
175	-	6.65	7.38	6.91	6.98
200	-	6.26	7.71	7.12	7.03
100	Terpal	5.98	6.63	5.21	5.94
150	Terpal	6.17	7.70	6.55	6.81
175	Terpal	6.24	7.55	7.01	6.93
200	Terpal	6.46	7.94	7.48	7.29
100	Moddus/Ter	5.52	6.87	5.53	5.97
150	Moddus/Ter	6.70	7.75	6.25	6.90
175	Moddus/Ter	6.35	7.62	6.18	6.72
200	Moddus/Ter	6.30	7.98	6.90	7.06
LSD (0.05)		*0.42*	*0.46*	*0.91*	

As with Optic, 2003 and 2004 saw good N dose responses up to 200 kg/ha, and both PGR treatments significantly increased the yield of the 150 N kg/ha programme (though not of the other levels of N). Again, in 2002, the yields tended to peak at 175 kg/ha N, with no differences between PGR treatments in this respect. In all years, the lowest level of applied N, 100 kg/ha, was significantly lower yielding than 150 kg/ha, in most cases.

Table 3. Grain nitrogen content (%) – cv Optic

N (kg/ha)	PGR	2002	2003	2004	3-year mean
100	-	1.56	1.58	1.40	1.51
150	-	1.69	1.74	1.47	1.63
175	-	1.85	1.82	1.53	1.73
200	-	1.88	1.91	1.60	1.80
100	Terpal	1.60	1.64	1.40	1.55
150	Terpal	1.64	1.69	1.44	1.59
175	Terpal	1.79	1.76	1.50	1.68
200	Terpal	1.83	1.89	1.55	1.76
100	Moddus/Ter	1.56	1.57	1.37	1.50
150	Moddus/Ter	1.66	1.73	1.42	1.60
175	Moddus/Ter	1.73	1.71	1.47	1.64
200	Moddus/Ter	1.87	1.82	1.54	1.74

The three-year mean figures indicate that the grain N levels remained within the desired range with applied N rates of 175 and 200 kg/ha. However, this includes a 'low grain N year' in 2004, where all treatments produced grain N of 1.60% or less, well below the targeted range of 1.65-1.85%. In 2002 and 2003, all 200 kg/ha N treatments produced grain close to or over 1.85%, making 175 kg/ha the maximum safe dose. This was the same for all PGR treatments, which themselves had no consistent effect on grain N levels

Table 4. Grain nitrogen content (%) – cv Cellar

N (kg/ha)	PGR	2002	2003	2004	3-year mean
100	-	1.59	1.69	1.45	1.58
150	-	1.71	1.77	1.55	1.68
175	-	1.79	1.86	1.59	1.75
200	-	1.91	1.97	1.67	1.85
100	Terpal	1.61	1.69	1.47	1.59
150	Terpal	1.65	1.77	1.54	1.65
175	Terpal	1.75	1.87	1.58	1.73
200	Terpal	1.86	1.95	1.64	1.82
100	Moddus/Ter	1.54	1.68	1.46	1.56
150	Moddus/Ter	1.65	1.70	1.51	1.62
175	Moddus/Ter	1.73	1.80	1.58	1.70
200	Moddus/Ter	1.85	1.93	1.67	1.82

As with Optic, the three-year means are misleading, as grain N levels were low in 2004, only exceeding 1.65% in untreated, and Moddus/Terpal treated plots respectively. In the other two years, 200 kg/ha applied N was consistently excessive in terms of grain N levels, as in some cases was 175 kg/ha. This supports the idea of Cellar as a ‘lower grain N variety’ than Optic, an observation made by others in the industry. Here, the optimum would have been 150 kg/ha (100kg/ha being too low, as with Optic, in one year at least,), and this again was not significantly influenced by PGR treatment.

Table 5. Screenings (% retained over 2.5mm sieve) – cv Optic

N (kg/ha)	PGR	2002	2003	2004	3-year mean
100	-	90.7	96.3	94.9	94.0
150	-	86.2	96.6	95.3	92.7
175	-	82.8	97.1	96.7	92.2
200	-	81.9	96.5	97.1	91.8
100	Terpal	91.6	96.6	96.5	94.9
150	Terpal	88.5	96.6	97.3	94.1
175	Terpal	88.4	96.5	96.9	93.9
200	Terpal	86.0	96.7	96.9	93.2
100	Moddus/Ter	92.1	96.5	97.1	95.2
150	Moddus/Ter	89.0	96.4	96.9	94.1
175	Moddus/Ter	85.8	96.9	97.1	93.3
200	Moddus/Ter	85.5	96.7	97.0	93.1

The accepted standard for grain retention is taken as 95% for the purposes of this project.
In 2002 the % retention figures were all low, and decreased further as applied N was increased. However this effect was less marked where PGRs were applied, and both the Terpal-only and the Moddus/Terpal sequence gave similar results in this respect. In 2003 and 2004, however, when retention was generally better, there were no clear effects of nitrogen dose or PGR treatment.

Table 6. Screenings (% retained over 2.5mm) – cv Cellar

N (kg/ha)	PGR	2002	2003	2004	3-year mean
100	-	91.3	95.8	96.2	94.4
150	-	92.0	96.0	95.9	94.6
175	-	91.6	95.8	96.0	94.5
200	-	87.7	95.4	96.1	93.1
100	Terpal	93.5	96.7	95.5	95.2
150	Terpal	91.9	95.7	96.4	94.7
175	Terpal	90.3	96.3	96.8	94.5
200	Terpal	90.4	95.7	96.4	94.2
100	Moddus/Ter	90.1	96.3	97.1	94.5
150	Moddus/Ter	92.5	96.4	96.8	95.2
175	Moddus/Ter	91.7	96.1	96.7	94.8
200	Moddus/Ter	91.9	96.0	97.1	95.0

There is also evidence here, in 2002, of growth regulators maintaining grain retention with the higher N rates, compared to untreated plots. However the differences in values are much smaller than with Optic, and in the other two years there is again no evidence of such a PGR effect, nor again any influence of N rate on % retention.

2. Morley

Table 7. Yields (t/ha) – cv Optic

N (kg/ha)	PGR	2002	2003	2004	3-year mean
100	-	7.97	7.30	4.26	6.51
150	-	8.03	8.12	3.96	6.70
175	-	8.02	8.30	4.38	6.90
200	-	7.71	8.07	4.28	6.69
100	Terpal	8.16	7.50	4.33	6.66
150	Terpal	8.32	8.20	4.50	7.01
175	Terpal	8.13	7.91	4.48	6.84
200	Terpal	8.14	8.19	4.72	7.02
100	Moddus/Ter	8.37	7.65	4.39	6.80
150	Moddus/Ter	8.47	7.94	4.44	6.95
175	Moddus/Ter	8.45	8.37	4.37	7.06
200	Moddus/Ter	8.25	8.04	4.33	6.87
LSD (0.05)		*NS*	*0.62*	*NS*	

Only in 2003 was there a yield response to increased N rate. With both the untreated control, and Terpal treatment, there was a significant increase in yield between 100 and 150 kg/ha N, but no significant responses with N rates above this. In 2002 the yield response to increased N was flat with all PGR treatments, and there were no yield responses to PGRs themselves at any N rate. In 2004 all yields were very low due to delayed establishment, and these results should be treated with caution.

Table 8. Yields (t/ha) – cv Cellar

N (kg/ha)	PGR	2002	2003	2004	3-year mean
100	-	7.90	7.39	3.98	6.42
150	-	8.21	7.76	4.59	6.85
175	-	8.24	7.70	4.50	6.81
200	-	8.07	7.74	4.81	6.87
100	Terpal	8.31	6.84	4.49	6.55
150	Terpal	8.66	8.14	4.75	7.18
175	Terpal	8.70	8.07	4.64	7.14
200	Terpal	8.70	8.12	4.39	7.07
100	Moddus/Ter	8.32	7.92	4.40	6.88
150	Moddus/Ter	8.86	7.37	4.30	6.84
175	Moddus/Ter	8.95	7.73	4.38	7.02
200	Moddus/Ter	8.89	8.18	4.66	7.24
LSD (0.05)		*NS*	*0.62*	*NS*	

In 2003, increased nitrogen rate again gave large increases in yield between 100 and 150 kg/ha N, but no response for further rate increases. In addition, this effect was not seen with the Moddus/Terpal sequence, which appeared to raise the yield of the 100kg/ha N treatment, thus levelling out the N response here. This contrasts with the Terpal-only treatment, which produced a significantly lower yield from the 100 kg/ha N rate compared to higher rates with this treatment. Similar increases between 100 and 150, with no increases beyond, are also evident in the 2002 figures, though the differences are smaller and not significant. Again, as with Optic, the 2004 yields were very low and variable.

Table 9. Grain nitrogen content (%) – cv Optic

N (kg/ha)	PGR	2002	2003	2004	3-year mean
100	-	1.52	1.56	1.93	1.67
150	-	1.80	1.76	2.15	1.90
175	-	1.99	1.85	2.18	2.01
200	-	2.03	1.91	2.18	2.04
100	Terpal	1.54	1.53	2.06	1.71
150	Terpal	1.84	1.74	2.09	1.89
175	Terpal	1.88	1.86	2.09	1.94
200	Terpal	1.99	1.90	2.16	2.02
100	Moddus/Ter	1.55	1.53	2.05	1.71
150	Moddus/Ter	1.87	1.67	2.15	1.90
175	Moddus/Ter	1.86	1.88	2.13	1.96
200	Moddus/Ter	1.94	1.90	2.21	2.02

As with the yield figures, there are large differences in grain N values for applied N rates between 100 and 150 kg/ha, in both 2002 and 2003. (The figures for 2004 reflect the low yields (qv) and again should be treated with caution). Whilst grain N continued to increase with higher N rates, those above 150 kg/ha tended to produce grain N values close to or above 1.85%.

There were no consistent effects of PGR treatment on grain N level for any of the applied N treatments.

Table 10. Grain nitrogen content (%) – cv Cellar

N (kg/ha)	PGR	2002	2003	2004	3-year mean
100	-	1.62	1.65	1.96	1.74
150	-	1.81	1.80	2.11	1.91
175	-	1.96	1.93	2.11	2.00
200	-	2.02	1.97	2.11	2.03
100	Terpal	1.61	1.56	1.99	1.72
150	Terpal	1.85	1.84	2.07	1.92
175	Terpal	1.90	1.87	2.10	1.96
200	Terpal	1.95	2.03	2.10	2.03
100	Moddus/Ter	1.62	1.64	2.01	1.76
150	Moddus/Ter	1.83	1.77	2.10	1.90
175	Moddus/Ter	1.94	1.88	2.07	1.96
200	Moddus/Ter	1.89	1.92	2.10	1.97

Again there were marked increases in grain N when applied N rate was increased from 100 to 150 kg/ha, though for this variety the values for the former treatment were close to the 1.65% minimum used here. As with Optic, N rates above 150 kg/ha tended to be excessive, and PGRs did not influence these responses.

Table 11. Screenings (% retained over 2.5mm sieve) – cv Optic

N (kg/ha)	PGR	2002	2003	2004	3-year mean
100	-	90.7	96.3	94.9	94.0
150	-	86.2	96.6	95.3	92.7
175	-	82.8	97.1	96.7	92.2
200	-	81.9	96.5	97.1	91.8
100	Terpal	91.6	96.6	96.5	94.9
150	Terpal	88.5	96.6	97.3	94.1
175	Terpal	88.4	96.5	96.9	93.9
200	Terpal	86.0	96.7	96.9	93.2
100	Moddus/Ter	92.1	96.5	97.1	95.2
150	Moddus/Ter	89.0	96.4	96.9	94.1
175	Moddus/Ter	85.8	96.9	97.1	93.3
200	Moddus/Ter	85.5	96.7	97.0	93.1

In 2002, as in the Andover trial, % retention was low, and further decreased by increases in applied nitrogen, and again the PGR treatments reduced this effect, giving better figures for the higher nitrogen rates. Again as at Andover, there were no clear effects of PGRs on retention in 2003 and 2004, when generally values for these were more acceptable.

Table 12. Screenings (% retained over 2.5mm) – cv Cellar

N (kg/ha)	PGR	2002	2003	2004	3-year mean
100	-	91.3	95.8	96.2	94.4
150	-	92.0	96.0	95.9	94.6
175	-	91.6	95.8	96.0	94.5
200	-	87.7	95.4	96.1	93.1
100	Terpal	93.5	96.7	95.5	95.2
150	Terpal	91.9	95.7	96.4	94.7
175	Terpal	90.3	96.3	96.8	94.5
200	Terpal	90.4	95.7	96.4	94.2
100	Moddus/Ter	90.1	96.3	97.1	94.5
150	Moddus/Ter	92.5	96.4	96.8	95.2
175	Moddus/Ter	91.7	96.1	96.7	94.8
200	Moddus/Ter	91.9	96.0	97.1	95.0

Once again values for 2002 were low, well below the 95% standard, and here, again as at Andover, the effects of PGRs on decreasing retention with higher N rates was less marked for this variety. No effects of PGR or applied N were seen in 2003 and 2004.

3. Perth

Table 13. Yields (t/ha) – cv Optic

N (kg/ha)	PGR	2002	2003	2004	3-year mean
100	-	5.84	7.68	6.75	6.76
150	-	5.63	8.25	7.00	6.96
175	-	5.43	7.74	6.76	6.64
200	-	5.20	8.09	7.25	6.85
100	Terpal	5.64	7.52	7.15	6.77
150	Terpal	5.52	8.45	7.48	7.15
175	Terpal	5.27	8.27	7.15	6.90
200	Terpal	5.32	8.19	7.10	6.87
100	Moddus/Ter	5.72	7.19	6.95	6.62
150	Moddus/Ter	5.63	8.08	7.45	7.05
175	Moddus/Ter	5.62	8.05	7.16	6.94
200	Moddus/Ter	5.38	8.69	7.62	7.23
LSD (0.05)		*0.28*	*0.67*	*0.66*	

At this site, yields were fairly low in 2002 and there was no response to increased N rate, nor any clear effect of PGR. In 2003, the yield responses were similar to those seen at other sites, with little or no response above 150 kg/ha N. In 2004 the yield responses to N rate were variable with no clear trends

Table 14. Yields (t/ha) – cv Cellar

N (kg/ha)	PGR	2002	2003	2004	3-year mean
100	-	5.86	7.59	8.04	7.16
150	-	5.88	8.45	7.89	7.41
175	-	6.12	8.64	8.69	7.82
200	-	6.04	8.74	8.46	7.75
100	Terpal	5.63	7.36	8.01	7.00
150	Terpal	5.79	8.20	7.99	7.33
175	Terpal	5.66	7.94	8.30	7.30
200	Terpal	5.59	8.49	8.51	7.53
100	Moddus/Ter	5.60	7.33	7.16	6.70
150	Moddus/Ter	5.67	8.25	8.48	7.47
175	Moddus/Ter	5.73	8.45	8.77	7.65
200	Moddus/Ter	5.80	8.51	8.55	7.62
LSD (0.05)		*0.28*	*0.67*	*0.66*	

As with Optic, yield responses were flat in 2002, whilst in 2003 there were responses in all PGR treatments to increased applied N from 100 to 150 kg/ha, but no response above this. This trend was also seen in 2004, but here there were yield responses up to 175 kg/ha N.

Table 15. Grain nitrogen content (%) – cv Optic

N (kg/ha)	PGR	2002	2003	2004	3-year mean
100	-	1.53	1.46	1.52	1.50
150	-	1.78	1.71	1.75	1.75
175	-	1.94	1.84	1.90	1.89
200	-	1.97	1.96	1.95	1.96
100	Terpal	1.48	1.44	1.75	1.56
150	Terpal	1.76	1.89	1.81	1.82
175	Terpal	1.85	1.77	1.91	1.84
200	Terpal	1.94	1.99	2.00	1.98
100	Moddus/Ter	1.50	1.44	1.61	1.52
150	Moddus/Ter	1.70	1.76	1.80	1.75
175	Moddus/Ter	1.84	1.86	1.85	1.85
200	Moddus/Ter	1.89	1.89	1.97	1.92

Each of the three years' results show that, as at Andover and Morley, if aiming for 1.65-1.85% nitrogen then 150 kg/ha applied N is the most appropriate, or 'safest' rate. However, for a target of less than 1.65% the total applied N needed to be less than this. Again, as in the Morley and Andover trials, there is no consistent influence of growth regulators on the nitrogen response.

Table 16. Grain nitrogen content (%) – cv Cellar

N (kg/ha)	PGR	2002	2003	2004	3-year mean
100	-	1.60	1.53	1.73	1.62
150	-	1.92	1.70	1.75	1.79
175	-	1.98	1.91	1.82	1.90
200	-	2.03	2.02	1.94	2.00
100	Terpal	1.64	1.55	1.69	1.63
150	Terpal	1.83	1.79	1.72	1.78
175	Terpal	1.92	1.84	1.82	1.86
200	Terpal	2.07	1.94	1.98	2.00
100	Moddus/Ter	1.58	1.56	1.62	1.59
150	Moddus/Ter	1.80	1.77	1.89	1.82
175	Moddus/Ter	2.00	1.81	1.84	1.88
200	Moddus/Ter	2.03	1.96	2.02	2.00

Cellar's tendency to produce higher grain N levels than Optic is reflected here, with the 150 kg/ha rate of nitrogen occasionally given values in excess of 1.85%, particularly in 2002. Again, as shown in the three-year means, there is no clear effect of growth regulators on the response of grain N to applied N.

Table 17. Screenings (% retained over 2.5mm sieve) – cv Optic

N (kg/ha)	PGR	2002	2003	2004	3-year mean
100	-	88.7	94.5	98.3	93.8
150	-	82.8	93.7	96.9	91.1
175	-	71.6	88.3	96.8	85.6
200	-	71.6	89.4	96.5	85.8
100	Terpal	88.4	95.4	96.1	93.3
150	Terpal	77.8	90.8	97.1	88.6
175	Terpal	78.9	91.9	97.5	89.4
200	Terpal	72.0	89.1	96.6	85.9
100	Moddus/Ter	89.1	96.6	95.8	93.8
150	Moddus/Ter	85.5	92.0	96.0	91.2
175	Moddus/Ter	76.0	90.6	95.4	87.3
200	Moddus/Ter	78.7	91.8	95.1	88.5

The retention values were particularly low in 2002 and decreased as the rate of applied nitrogen was increased. Here, there is a growth regulator effect in that both the Terpal treatment, and the Moddus/Terpal sequence, appeared to keep the % retention up at the higher N rates, though the levels overall were well below the standard required. In other years, when retention values were closer to that required by the market, these PGR effects were not seen.

Table 18. Screenings (% retained over 2.5mm) – cv Cellar

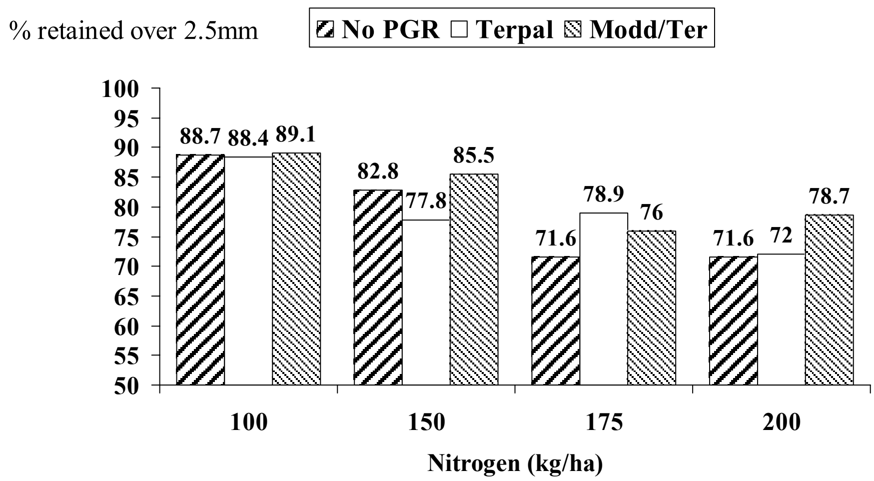
N (kg/ha)	PGR	2002	2003	2004	3-year mean
100	-	90.6	97.7	97.6	95.3
150	-	81.1	95.6	97.9	91.5
175	-	85.5	94.1	97.6	92.4
200	-	83.1	91.1	97.9	90.7
100	Terpal	89.3	97.8	97.8	95.0
150	Terpal	86.2	95.5	98.0	93.2
175	Terpal	81.5	94.4	97.6	91.2
200	Terpal	80.7	94.7	97.4	90.9
100	Moddus/Ter	88.4	97.2	96.9	94.2
150	Moddus/Ter	85.4	95.8	97.3	92.8
175	Moddus/Ter	81.8	96.7	98.3	92.3
200	Moddus/Ter	80.8	93.2	98.1	90.7

In Cellar, the 2002 figures show again low grain retention, but here no beneficial effect from PGRs. However there is evidence of such an effect, albeit smaller than seen in Optic in 2002, in the 2003 figures. In 2004, again when values were nearer to or above the required standard, there were no such effects.

In 2002 at this site growing conditions at this site were such that tiller production was excessive, and fertile tiller (ear) numbers were often in excess of 900/m^2. This would be a contributory factor to the high screenings (low retention) recorded. It was also noted that the PGR programmes appeared to moderate these ear numbers, this being reflected in the retention figures (figs 1&2)

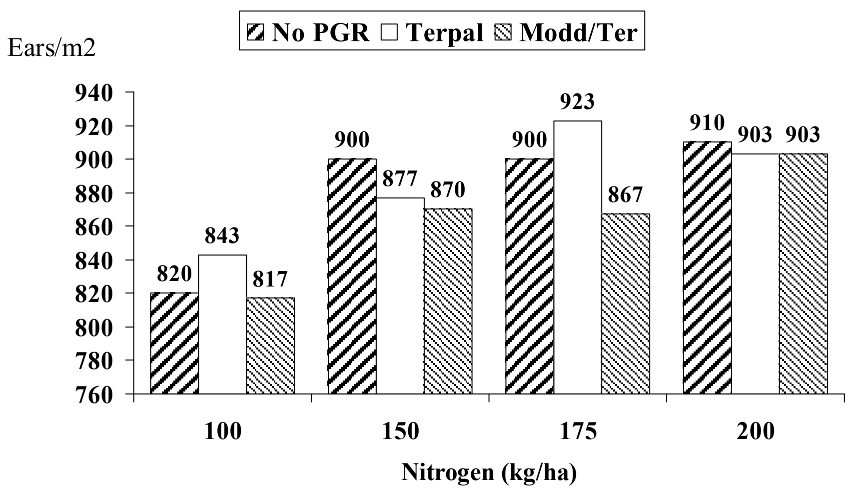
Similar effects were seen at Morley and Andover in 2002, though to a lesser extent, and it is likely that growing conditions in that year encouraged excessive tillering generally. In other years, when ear numbers were in a more typical range of 600-800/m^2, these PGR effects were not seen.

Figure 1: Nitrogen dose and PGR response –sieved grain % retention (Perth 2002)



LSD 5.2%

Figure 2: Nitrogen dose and PGR response –ear numbers (Perth 2002)



Lodging

Lodging was infrequent throughout the duration and locations of this project. In 2002, however, lodging was recorded at two sites

Table 19. Lodging scores (% area lodged**)**

N (kg/ha)	PGR	Andover 2002, Optic	Andover 2002, Cellar	Morley 2002, Cellar
100	-	7	0	0
150	-	30	12	3
175	-	10	37	25
200	-	20	33	22
100	Terpal	0	0	0
150	Terpal	7	3	0
175	Terpal	3	25	0
200	Terpal	3	37	0
100	Moddus/Ter	0	0	0
150	Moddus/Ter	7	3	0
175	Moddus/Ter	0	15	0
200	Moddus/Ter	23	43	0

In most cases the higher levels of applied N have resulted in more lodging, and the growth regulator programmes have reduced this, eliminating it at Morley. However the growth regulators were frequently less effective when 200 kg/ha N was applied. Where they have been effective, the Terpal-only treatment was as effective at reducing lodging as the Moddus-Terpal sequence. As seen in earlier tables these PGR effects did not significantly influence yield.

Discussion

The responses to growth regulators seen with the range of nitrogen programmes have been governed by the weather patterns over the three years. In 2002 most of the country experienced an early spring drought, which would have inhibited the uptake of applied nitrogen. When the dry spell ended, this nitrogen was freely available at a time when the crop would normally have been losing tillers as stem extension progressed. The result was the survival of tillers which would otherwise have been lost, leading to higher than normal ear populations. This was a consistent effect seen at all the sites in this trial series, and as a result the % grain retention (screenings) were affected (the higher ear populations leading to smaller grains). Screenings were particularly high in the Perth trial, and here particularly there were benefits from the use of growth regulators. The Moddus/Terpal sequence in particular, with Moddus applied at the end of tillering, appeared to moderate this tillering effect and reduced the ear

population thereby improving grain retention. This effect was also seen, albeit to a lesser extent, at Andover and Morley that year.
Another consequence of the higher ear population appeared to be crop lodging. Lodging was infrequent in the trial series, but was evident in 2002 at Andover and Morley, and was controlled well at both sites with growth regulators.
These effects were not seen in the yield or grain nitrogen data, but if the growth regulators maintained the % retention in the required range for a particular market, then they would have influenced the profitability of the crop.
However, all these effects were seen in an unusual season where growing conditions led to excessive ear production. In 2003 and 2004, ear numbers were more typical (600-800/m^2) and in these years the growth regulator treatments were far less influential on grain yield and quality. There was little or no lodging in these years at any of the sites; consequently there was very little evidence of a benefit from a growth regulator, even at an applied nitrogen rate of 200 kg/ha.
In addition, the higher N rates of 175 or 200 kg/ha frequently produced grain nitrogen levels above 1.85%. This was particularly the case with Cellar, whereas Optic occasionally remained below 1.85 % with 175 kg/ha N. The Andover site, on a light chalky soil, also tended to produce lower grain N, with 200 kg/ha applied N producing grain in the target range in many cases, again particularly with Optic. Despite this the yield response to increasing N rate usually peaked at 150 kg/ha N, with few significant yield responses to N rates above this. Hence this figure seems to be appropriate for the majority of situations, being high enough to give a high yield, producing grain N levels within the target range, whilst not encouraging excessive tillering or ear production, lodging, or high screenings, that may require a growth regulator. In other words, the nitrogen rates which were likely to require a growth regulator treatment, either for lodging control or, with the sequence including the early PGR treatment, to regulate ear numbers, tended to be too high for optimum grain quality and yield.

There were exceptions to this: the high ear populations seen in 2002 led to useful effects from growth regulators, but again most of these effects were seen with the higher nitrogen rates. Also, in 2004 at Morley, yields were low enough to produce excessive grain N with all the nitrogen rates evaluated. In Scotland, where there is a significant market for barley with grain N below 1.65%, nitrogen rates of 175 or 200 kg/ha would clearly be excessive, and whilst not tested extensively here, rates lower than 150 kg/ha are likely to be required. This would further weaken the case for growth regulator treatment. (In addition, the Perth trials trended to produce the highest yields for the 100 kg/ha N rate, which would be useful if aiming for a lower grain N market).
Nevertheless with a target grain N range of 1.65-1.85%, a total nitrogen application of 150 kg/ha N was the most reliable, and at this level of nitrogen there was little evidence of a benefit from growth regulators at any of the three trial sites.

Trial 2. Influence of seed rate on nitrogen and growth regulator response

Materials and methods

Spring barley trials were established at three locations; Perth, Cirencester (Glos), and Caythorpe (Lincs), sown at three seed rates; 200, 300 and 400 seeds/m^2

Each of these seed rate plots then received either 100 or 175 kg/ha applied nitrogen, with a further factor of a PGR treatment applied across all combinations, i.e.
3 seed rates x 2 nitrogen rates, +/- PGR, = 12 treatments.
All treatments were applied to two varieties, Optic and Cellar.
Growth regulator treatment: Moddus 0.2 l/ha GS30, followed by Terpal, 0.5 l/ha GS39-49
All trials were grown according to typical local husbandry. However, all disease control programmes involved two strobilurin-based sprays.
Trials were assessed for plant establishment, fertile tiller (ear) number, grain yield, grain nitrogen content and screenings.
The trials were conducted in 2002, 2003 and 2004.

Results

Plant establishment
The mean establishment figures for the three seed rates used, at the three locations, are given in table 1.

Seeds/m^2	Cirencester		Caythorpe		Perth	
	Plants/m^2	Range	Plants/m^2	Range	Plants/m^2	Range
Optic						
200	142	128-183	140	124-154	188	160-200
300	213	182-250	200	172-225	265	254-279
400	259	206-314	219	189-264	345	306-361
Cellar						
200	184	164-219	144	126-165	191	172-200
300	207	161-248	195	161-215	291	257-300
400	284	224-312	247	232-268	368	288-400

Yield and grain quality results

1. Cirencester

Table 2: Yield (t/ha) cv Optic

Nitrogen (kg/ha)	Seed rate/m^2	PGR	2002	2003	2004	3 yr mean
100	200	None	7.25	6.41	4.89	6.18
100	200	Moddus/Terpal	7.54	6.19	5.17	6.30
100	300	None	7.67	6.18	5.43	6.43
100	300	Mod/Ter	7.59	6.30	5.66	6.52
100	400	None	7.90	6.51	5.18	6.53
100	400	Moddus/Ter	7.99	6.71	5.51	6.74
175	200	None	7.49	6.87	4.92	6.43
175	200	Mod/Ter	7.63	6.33	5.07	6.34
175	300	None	8.02	6.54	5.63	6.73
175	300	Mod/Ter	7.97	6.61	5.92	6.83
175	400	None	8.16	6.67	5.99	6.94
175	400	Moddus/Ter	8.33	6.78	6.25	7.12
LSD (0.05)			*0.41*	*0.84*	*0.60*	

In 2002, for both N treatments, both the 300 and 400 seed rates significantly out-yielded 200, when no PGR was applied. However, with a PGR programme, the yields of the lower seed rates were improved to the extent that only the 400 significantly out-yielded the 200 rate. Therefore the PGR programme appeared to improve the yield of the lower seed rate more than that of the higher rates. In 2003 the lowest seed rate gave the highest yields, with little or no benefit from the PGR, nor any significant differences between the two N treatments. Over the three years, the higher level of N has given small increases in yield, with the optimum seed rate around 300/m^2, and small yield benefits throughout from the PGR programme, which would not have been cost-effective.

Table 3: Yield (t/ha) cv Cellar

Nitrogen (kg/ha)	Seed rate/m^2	PGR	2002	2003	2004	3 yr mean
100	200	None	7.85	5.63	5.09	6.19
100	200	Moddus/Terpal	7.66	5.43	4.92	6.00
100	300	None	7.95	5.42	6.29	6.55
100	300	Mod/Ter	8.14	5.66	5.81	6.54
100	400	None	7.98	5.88	5.12	6.33
100	400	Moddus/Ter	8.38	5.27	5.12	6.26
175	200	None	8.31	6.01	5.57	6.63
175	200	Mod/Ter	8.70	5.43	5.76	6.63
175	300	None	8.70	5.78	6.11	6.86
175	300	Mod/Ter	8.95	5.89	5.92	6.92
175	400	None	8.78	6.09	5.99	6.95
175	400	Moddus/Ter	9.05	5.79	5.76	6.87
LSD (0.05)			*0.41*	*0.84*	*0.60*	

In 2002 (the highest-yielding year, as with Optic), the crop responded well to the higher N rate, and, with this rate, the seed rate response is more in favour of the higher seed rate. There was, however, only one significant response to the PGR, with the 400 seed rate and 100 kg/ha N. In the later years, the seed rate response was fairly flat, and although the higher N gave higher yields, this did not alter the seed rate response. Also, the PGR programme in most cases reduced yield, though not significantly. The three year means show an optimum seed rate of around 300/m^2, though the 200 rate performed better with the higher N rate. Overall there were no PGR interactions with these responses.

Table 4: Grain nitrogen (%) cv Optic

Nitrogen (kg/ha)	Seed rate/m^2	PGR	2002	2003	2004	3 yr mean
100	200	None	1.62	1.72	1.70	1.68
100	200	Moddus/Terpal	1.78	1.75	1.73	1.75
100	300	None	1.68	1.69	1.55	1.64
100	300	Mod/Ter	1.62	1.73	1.56	1.64
100	400	None	1.64	1.67	1.71	1.67
100	400	Moddus/Ter	1.57	1.68	1.64	1.63
175	200	None	1.96	2.06	2.13	2.05
175	200	Mod/Ter	1.90	2.07	2.08	2.02
175	300	None	1.87	2.05	1.98	1.97
175	300	Mod/Ter	1.91	2.04	2.01	1.99
175	400	None	1.90	1.99	1.91	1.93
175	400	Moddus/Ter	1.84	2.04	1.90	1.93

In each year the higher N rate has given higher (excessive) grain N levels. There are very small and insignificant reductions in grain N with the higher seed rates, but these do not compensate for the applied nitrogen effect. The PGR programme has not influenced grain N levels with any seed rate or either N rate.

Table 5: Grain nitrogen (%) cv Cellar

Nitrogen (kg/ha)	Seed rate/m^2	PGR	2002	2003	2004	3 yr mean
100	200	None	1.72	1.73	1.70	1.72
100	200	Moddus/Terpal	1.71	1.81	1.69	1.74
100	300	None	1.70	1.77	1.62	1.70
100	300	Mod/Ter	1.66	1.73	1.62	1.67
100	400	None	1.56	1.68	1.67	1.64
100	400	Moddus/Ter	1.60	1.77	1.56	1.64
175	200	None	1.94	1.99	2.17	2.03
175	200	Mod/Ter	1.88	2.03	2.12	2.01
175	300	None	1.87	1.98	2.08	1.98
175	300	Mod/Ter	1.92	2.04	2.02	1.99
175	400	None	1.84	2.01	1.85	1.90
175	400	Moddus/Ter	1.85	2.04	1.93	1.94

As with Optic, Cellar has also produced excessive grain N with 175 kg/ha applied N, and although there are more consistently lower grain N values with the higher seed rates, this is evident more with the 100kg/ha N rate than with 175 kg/ha. Again there are small and inconsistent effects of PGR on grain N.

Table 6: Screenings (% retention over 2.5mm sieve) cv Optic

Nitrogen (kg/ha)	Seed rate/m^2	PGR	2002	2003	2004	3 yr mean
100	200	None	93.7	95.4	98.6	95.9
100	200	Moddus/Terpal	93.7	95.0	98.5	95.7
100	300	None	92.7	94.5	98.6	95.3
100	300	Mod/Ter	94.5	94.4	98.8	95.9
100	400	None	93.8	92.2	98.4	94.8
100	400	Moddus/Ter	94.4	92.8	98.6	95.3
175	200	None	87.9	93.5	98.7	93.4
175	200	Mod/Ter	92.8	94.1	98.6	95.2
175	300	None	92.0	89.7	98.3	93.3
175	300	Mod/Ter	92.1	90.1	98.6	93.6
175	400	None	88.5	87.7	98.1	91.4
175	400	Moddus/Ter	90.9	89.4	98.6	93.0

Higher seed rates tended to give lower retention values (higher screenings), particularly in 2003. Nitrogen rate did not have a consistent effect on this, though the PGR treatment appeared to improve retention where this was low. In 2004, when retention levels were good, there were no differences in the values between any of the treatments.

Table 7: Screenings (% retention over 2.5mm sieve) cv Cellar

Nitrogen (kg/ha)	Seed rate/m^2	PGR	2002	2003	2004	2 yr mean
100	200	None	95.7	93.0	99.0	95.9
100	200	Moddus/Terpal	96.0	92.8	98.0	95.6
100	300	None	95.3	91.4	98.5	95.1
100	300	Mod/Ter	96.1	93.3	98.9	96.1
100	400	None	95.8	92.1	98.2	95.4
100	400	Moddus/Ter	94.9	90.0	98.5	94.5
175	200	None	94.9	86.6	97.9	93.1
175	200	Mod/Ter	95.4	88.6	98.6	94.2
175	300	None	95.2	88.9	98.9	94.3
175	300	Mod/Ter	94.0	87.6	98.4	93.3
175	400	None	94.2	79.5	97.9	90.5
175	400	Moddus/Ter	95.0	86.7	98.0	93.2

In Cellar, nitrogen rate had a greater influence on screenings than seed rate, particularly in 2003. PGR had little effect, except at the highest seed rate with 175 kg/ha N where in 2003 the PGR treatment raised the % retention by 7.2%. As with Optic, there were no treatment effects in 2004 when % retention was high.

2. Caythorpe

Table 8: Yield (t/ha) cv Optic

Nitrogen (kg/ha)	Seed rate/m^2	PGR	2002	2003	2004	3 yr mean
100	200	None	6.14	5.78	7.15	6.36
100	200	Moddus/Terpal	5.96	5.56	7.19	6.24
100	300	None	6.33	5.79	7.39	6.50
100	300	Mod/Ter	6.39	5.80	7.38	6.52
100	400	None	6.25	5.36	6.99	6.20
100	400	Moddus/Ter	6.43	5.54	7.02	6.33
175	200	None	5.94	6.27	7.40	6.54
175	200	Mod/Ter	5.85	6.06	7.65	6.52
175	300	None	6.31	5.91	7.47	6.56
175	300	Mod/Ter	6.40	6.18	7.73	6.77
175	400	None	5.90	6.00	7.68	6.53
175	400	Moddus/Ter	6.73	6.31	7.96	7.00
LSD (0.05)			*0.51*	*0.59*	*0.72*	

In 2002, there was no consistent response to the higher N rate, but in the latter two years 175 kg/ha N consistently out-yielded 100 kg/ha. However in none of the three years was there a consistent response to seed rate, making 200 seeds the optimum in each case. This response was not influenced by nitrogen rate or PGR treatment, though the latter did consistently improve the yield of the highest seed rate with the higher N rate (400, and 175 respectively) in all three years of the trial.

Table 9: Yield (t/ha) cv Cellar

Nitrogen (kg/ha)	Seed rate/m^2	PGR	2002	2003	2004	3 yr mean
100	200	None	6.26	5.29	6.95	6.17
100	200	Moddus/Terpal	6.40	5.23	7.49	6.37
100	300	None	6.67	5.55	6.77	6.33
100	300	Mod/Ter	6.75	5.89	7.15	6.60
100	400	None	6.88	5.27	6.46	6.20
100	400	Moddus/Ter	6.84	5.58	7.52	6.65
175	200	None	6.75	5.85	6.97	6.52
175	200	Mod/Ter	6.87	5.60	7.68	6.72
175	300	None	6.49	6.07	7.44	6.67
175	300	Mod/Ter	7.03	6.16	7.80	7.00
175	400	None	7.00	5.61	7.63	6.75
175	400	Moddus/Ter	7.10	6.31	7.62	7.01
LSD (0.05)			*0.51*	*0.59*	*0.72*	

In 2002 with 100 kg/ha N, and 2004 with 175 kg/ha N, there were small, non-significant, yield increases from 300 seeds/m^2 over 200 seeds. Otherwise there isn't a clear seed rate response. Growth regulator treatment has occasionally given significant yield responses (in 2004 with 100 kg/ha N and 400 seeds/m^2, and in 2002 with 175 kg/ha N and 300 seeds). However the three-year mean figures show this response to be consistent across all treatments, if not always very large.

Table 10: Grain nitrogen (%) cv Optic

Nitrogen (kg/ha)	Seed rate/m^2	PGR	2002	2003	2004	3 yr mean
100	200	None	1.82	1.63	1.75	1.73
100	200	Moddus/Terpal	1.80	1.55	1.65	1.67
100	300	None	1.69	1.54	1.76	1.66
100	300	Mod/Ter	1.78	1.53	1.91	1.74
100	400	None	1.71	1.55	1.61	1.62
100	400	Moddus/Ter	1.72	1.53	1.91	1.72
175	200	None	1.97	1.76	2.10	1.94
175	200	Mod/Ter	1.92	1.82	1.80	1.85
175	300	None	1.90	1.81	1.89	1.87
175	300	Mod/Ter	1.89	1.80	1.89	1.86
175	400	None	1.97	1.75	1.92	1.88
175	400	Moddus/Ter	1.95	1.72	1.89	1.85

In 2002 and 2003 the higher nitrogen rate produced excessive grain N, with the 100 kg/ha rate generally in the target range, whilst in 2003 the grain N levels were more typical, being too low with 100 kg/ha and within the target range with 175 kg/ha N. Seed rate, and PGR effects on grain N were inconsistent.

Table 11: Grain nitrogen (%) cv Cellar

Nitrogen (kg/ha)	Seed rate/m^2	PGR	2002	2003	2004	3 yr mean
100	200	None	1.79	1.59	1.67	1.68
100	200	Moddus/Terpal	1.83	1.60	1.64	1.69
100	300	None	1.77	1.58	1.68	1.68
100	300	Mod/Ter	1.87	1.55	1.59	1.67
100	400	None	1.83	1.53	1.78	1.71
100	400	Moddus/Ter	1.77	1.55	1.79	1.70
175	200	None	1.95	1.83	2.00	1.93
175	200	Mod/Ter	2.04	1.85	1.87	1.92
175	300	None	1.97	1.75	1.89	1.87
175	300	Mod/Ter	1.97	1.84	1.88	1.90
175	400	None	2.01	1.77	1.86	1.88
175	400	Moddus/Ter	1.96	1.79	1.94	1.90

Again 175 kg/ha was too high for optimum grain N in 2002 and 2004, but acceptable in 2003, as with Optic above. However, again there were no clear effects of seed rate or PGR treatment on grain N levels.

Table 12: Screenings (% retention over 2.5mm sieve) cv Cellar

Nitrogen (kg/ha)	Seed rate/m^2	PGR	2002	2003	2004	3 yr mean
100	200	None	95.6	97.5	98.7	97.3
100	200	Moddus/Terpal	96.6	96.8	99.0	97.5
100	300	None	95.2	95.7	98.1	96.3
100	300	Mod/Ter	97.7	96.3	98.2	97.4
100	400	None	95.7	95.7	98.4	96.6
100	400	Moddus/Ter	94.7	95.1	99.0	96.3
175	200	None	94.0	97.1	98.0	96.4
175	200	Mod/Ter	95.2	96.6	98.8	96.9
175	300	None	89.2	94.4	98.1	93.9
175	300	Mod/Ter	93.9	95.7	98.7	96.1
175	400	None	89.6	95.3	98.1	94.3
175	400	Moddus/Ter	94.2	95.4	99.1	96.2

As in the Perth trial in the previous trial series (trial 1), 2002 produced low retention figures with the higher nitrogen rates, and these were raised again by the growth regulator sequence. The effect was not seen in 2003, though the higher nitrogen rates again appeared to lower the % retention. In 2004, with high retention values, there were no consistent treatment effects, either from nitrogen or growth regulator.

The % retention values for Optic showed similar treatment interactions. The figures are given in the Appendix.

3. Perth

Table 13: Yield (t/ha) cv Optic

Nitrogen (kg/ha)	Seed rate/m^2	PGR	2002	2003	2004	3 yr mean
100	200	None	5.54	6.90	6.79	6.41
100	200	Moddus/Terpal	5.27	7.32	7.24	6.61
100	300	None	5.55	7.28	7.29	6.71
100	300	Mod/Ter	5.52	7.61	7.20	6.78
100	400	None	5.48	7.15	7.07	6.57
100	400	Moddus/Ter	5.32	7.68	7.16	6.72
175	200	None	5.37	7.99	7.20	6.85
175	200	Mod/Ter	5.52	8.09	7.36	6.99
175	300	None	5.56	8.04	7.35	6.98
175	300	Mod/Ter	5.43	8.48	7.17	7.03
175	400	None	5.21	7.95	7.28	6.81
175	400	Moddus/Ter	5.49	8.34	7.53	7.12
LSD (0.05)			*0.36*	*0.75*	*0.62*	

In 2002, there was no response to increased seed rate for either nitrogen treatment, and no response to the higher nitrogen rate, or to a PGR treatment with any of these combinations. In 2003, however, there was a consistent tendency for PGR treatment to increase yield, for comparable seed rate/N treatments, and for the optimum seed rate to be higher (300 seeds/m^2) when PGR was applied. Without PGR, the 200 seed rate gave similar yields to the higher rates. In 2004 the responses to the various treatments were smaller. Overall (three-year means) indicate slightly higher yields from the higher N rate, but little or no response to seed rate or PGR.

Table 14: Yield (t/ha) cv Cellar

Nitrogen (kg/ha)	Seed rate/m^2	PGR	2002	2003	2004	3 yr mean
100	200	None	5.49	7.16	7.93	6.86
100	200	Moddus/Terpal	5.36	7.25	7.51	6.71
100	300	None	5.83	7.01	7.68	6.84
100	300	Mod/Ter	5.54	7.23	7.26	6.68
100	400	None	5.62	6.87	7.55	6.68
100	400	Moddus/Ter	5.46	7.61	7.88	6.98
175	200	None	5.98	8.33	8.10	7.47
175	200	Mod/Ter	5.79	8.15	8.46	7.47
175	300	None	5.93	8.27	8.60	7.60
175	300	Mod/Ter	5.78	8.51	8.73	7.67
175	400	None	6.00	8.23	8.67	7.63
175	400	Moddus/Ter	5.88	8.22	8.52	7.54
LSD (0.05)			*0.36*	*0.75*	*0.62*	

In 2002, in contrast to Optic, there was a slight response to increased seed rate with the lower N rate. This effect was only seen again in 2004 with the higher nitrogen rate. In addition, in 2002 the PGR programme consistently reduced yield, but not by statistically significant amounts. In contrast, the PGR treatment increased yield considerably (though not quite statistically significant) in 2003 when applied to the highest seed rate treated with the lower N rate. 2003 and 2004 saw the largest response to increased N rate, but within these treatment groups responses to seed rate and PGR were inconsistent.

Table 15: Grain nitrogen (%) cv Optic

Nitrogen (kg/ha)	Seed rate/m^2	PGR	2002	2003	2004	3 yr mean
100	200	None	1.50	1.50	1.55	1.52
100	200	Moddus/Terpal	1.57	1.53	1.60	1.57
100	300	None	1.45	1.44	1.50	1.46
100	300	Mod/Ter	1.46	1.47	1.57	1.50
100	400	None	1.42	1.49	1.61	1.51
100	400	Moddus/Ter	1.50	1.59	1.55	1.55
175	200	None	1.90	1.91	1.84	1.88
175	200	Mod/Ter	1.91	1.84	1.84	1.86
175	300	None	1.84	1.78	1.86	1.83
175	300	Mod/Ter	1.82	1.87	1.87	1.85
175	400	None	1.86	1.78	1.76	1.80
175	400	Moddus/Ter	1.88	1.78	1.76	1.81

The lower N rate (100 kg/ha) consistently produced grain N below 1.65%, whilst 175 kg/ha gave values close to the upper limit of the target range. These tended to be lower with the higher seed rates, (bringing them into the target range), though these differences were small. There were no consistent effects from the PGR treatment, though in the majority of cases grain N was slightly increased when PGR was applied.

Table 16: Grain nitrogen (%) cv Cellar

Nitrogen (kg/ha)	Seed rate/m^2	PGR	2002	2003	2004	3 yr mean
100	200	None	1.67	1.60	1.70	1.66
100	200	Moddus/Terpal	1.68	1.57	1.61	1.62
100	300	None	1.58	1.53	1.64	1.58
100	300	Mod/Ter	1.59	1.67	1.53	1.60
100	400	None	1.55	1.55	1.65	1.58
100	400	Moddus/Ter	1.50	1.59	1.60	1.56
175	200	None	1.93	2.04	1.93	1.97
175	200	Mod/Ter	1.85	2.04	2.00	1.96
175	300	None	1.96	2.00	1.87	1.94
175	300	Mod/Ter	1.96	1.85	1.82	1.88
175	400	None	1.94	1.87	1.88	1.90
175	400	Moddus/Ter	1.99	1.98	1.88	1.95

Again 175 kg/ha gave grain N above 1.85% in most cases, and 100 kg/ha values below 1.65% in most cases. There is again a slight tendency for higher seed rates to give lower grain N, for both applied N rates. PGR again did not consistently influence these interactions.

Table 17: Screenings (% retention over 2.5mm sieve) cv Optic

Nitrogen (kg/ha)	Seed rate/m^2	PGR	2002	2003	2004	3 yr mean
100	200	None	86.3	95.8	98.1	93.4
100	200	Moddus/Terpal	84.7	97.5	97.2	93.1
100	300	None	88.6	95.3	97.5	93.8
100	300	Mod/Ter	88.7	97.1	97.4	94.4
100	400	None	88.8	94.2	96.8	93.3
100	400	Moddus/Ter	88.4	96.4	97.1	94.0
175	200	None	75.8	94.6	97.9	89.4
175	200	Mod/Ter	72.0	94.4	94.8	87.1
175	300	None	77.2	93.2	96.2	88.9
175	300	Mod/Ter	78.1	93.8	94.8	88.9
175	400	None	76.8	91.3	98.0	88.7
175	400	Moddus/Ter	77.8	93.0	96.7	89.2

In 2002 % retention was low (see also trial 1) and the higher N rate has reduced it further. Seed rate and PGR treatment has had little effect. A similar, but smaller effect was seen in 2003, where in many cases the PGR treatment improved retention slightly. In this year the higher seed rates also caused small reductions in retention. In 2004 there was no obvious effect of nitrogen rate or seed rate, but with the higher N rate, the PGR treatment reduced % retention.

Table 18: Screenings (% retention over 2.5mm sieve) cv Cellar

Nitrogen (kg/ha)	Seed rate/m^2	PGR	2002	2003	2004	3 yr mean
100	200	None	88.2	98.0	96.9	94.4
100	200	Moddus/Terpal	87.7	98.3	97.7	94.6
100	300	None	87.8	96.7	97.7	94.1
100	300	Mod/Ter	89.9	97.4	97.2	94.8
100	400	None	87.4	97.4	97.5	94.1
100	400	Moddus/Ter	92.7	97.9	97.5	96.0
175	200	None	87.3	95.0	97.4	93.2
175	200	Mod/Ter	85.3	96.2	96.0	92.5
175	300	None	83.9	94.3	97.4	91.9
175	300	Mod/Ter	83.9	97.2	98.3	93.1
175	400	None	82.5	93.6	98.0	91.4
175	400	Moddus/Ter	85.0	95.0	97.3	92.4

The effect of N rate on retention in 2002 was not as great as with Optic. Again in 2003 the PGR treatment has improved retention slightly. In 2002 the higher seed rates produced lower retention figures, with the higher applied N rate, but this was not seen in other years.

Fertile tiller (ear) populations

Plant population, and subsequent growth regulator treatment, would be expected to influence the ear numbers of the various treatments, which in turn may influence grain quality. Table 19 gives the fertile tiller numbers for the three sites, expressed as three-year means.

Table 19. Fertile tiller (ear) numbers/m^2 - Optic

Nitrogen (kg/ha)	Seed rate/m^2	PGR	Cirencester	Caythorpe	Perth
100	200	None	503	521	682
100	200	Moddus/Terpal	496	519	730
100	300	None	564	527	760
100	300	Mod/Ter	544	522	756
100	400	None	602	489	791
100	400	Moddus/Ter	636	513	753
175	200	None	549	535	793
175	200	Mod/Ter	524	528	774
175	300	None	615	540	829
175	300	Mod/Ter	628	510	834
175	400	None	649	555	892
175	400	Moddus/Ter	627	534	838

Table 20. Fertile tiller (ear) numbers/m^2 - Cellar

Nitrogen (kg/ha)	Seed rate/m^2	PGR	Cirencester	Caythorpe	Perth
100	200	None	543	485	688
100	200	Moddus/Terpal	518	504	709
100	300	None	539	527	752
100	300	Mod/Ter	572	546	727
100	400	None	600	571	822
100	400	Moddus/Ter	609	552	749
175	200	None	553	503	760
175	200	Mod/Ter	538	502	749
175	300	None	598	544	859
175	300	Mod/Ter	612	519	857
175	400	None	616	543	851
175	400	Moddus/Ter	648	534	886

Optic: at Cirencester and Perth, both the higher nitrogen rate and the higher seed rates increased ear numbers. These increases were seen both with and without PGR, with the exception of the highest N rate (175) and the highest seed rate, (400) where there was no increase over the corresponding treatment with 300 seeds/m^2. At Caythorpe there were no consistent effects of treatment on ear number.

Cellar: again the increases in ear numbers have resulted from the higher nitrogen rate and seed rates, but with this variety there is less evidence of any growth regulator influence on this.

Discussion

In terms of grain yield, there were several cases where 300 seeds/m^2 out-yielded 200, with little or no further increase from 400 seeds. In other cases, for example at Caythorpe in 2002 and 2003 (Optic), this difference between 200 and 300 was smaller, making 200 the optimum for most comparisons. Similarly, at the Perth site, results with Optic and Cellar saw little response to seed rate above 200, with only occasional examples of 300 being the optimum.

Nitrogen rate had a more consistent effect on yield, and not surprisingly the 175 kg/ha rate generally producing higher yields than the 100 kg/ha rate. However, the seed rate response, in yield terms, did not vary within the two nitrogen rates.

In 2002 and 2004, at Cirencester and Caythorpe, and in all three years at Perth, there was a tendency for grain nitrogen level to come down as seed rate was increased, and this effect was more evident when the higher rate of nitrogen was applied. This higher rate produced grain nitrogen above 1.85% in many cases; however the reduction resulting from higher seed rates was not always sufficient to bring it back below this. Overall, therefore, there were few advantages to the highest seed rate tested, the optimum for yield being either 200 or 300/m^2, and any seed rate effects on grain N being seen with an applied N rate which was excessive for optimum grain quality.

The effects of a growth regulator programme were most often seen at the higher end of the input range. With a seed rate of 400 seeds/m^2, and the higher (175 kg/ha) rate of applied nitrogen, the growth regulator sequence consistently gave positive yield responses at all sites, though the differences were not always statistically significant. However there were few examples of growth regulator treatment influencing grain nitrogen level, so if this was excessive at this high input level then the growth regulator did not remedy this.

Of the three trial sites, Caythorpe was the least responsive to the experimental treatments, with small yield increases from the higher nitrogen rate, and little influence on yield and quality from seed rates or growth regulators. Perth showed the largest response in grain nitrogen level to applied nitrogen rate, and the difference between Optic and Cellar was more apparent, the latter consistently producing higher grain nitrogen for comparable treatments.

Over all the sites, growth regulator treatment had the smallest effect on yield and quality. Nitrogen rate had a larger effect, and higher seed rates occasionally increased yield and lowered grain nitrogen, though in most cases the optimum seed rate was either 200 or 300/m^2. Nitrogen rate and seed rate also had the largest influence on ear numbers.

Trial 3. Interaction between nitrogen timing and application level in the presence or absence of growth regulators.

Materials and methods

Field trials were established at three locations, Perth, Andover (Hants) and Morley (Norfolk). Plots were sown at a standard seed rate, and treated with a range of nitrogen amounts and timings, together with a growth regulator programme, as follows

N totals: 100, 150, 175, 200 kg/ha N
N timings: all the above totals applied as:
a) a single dose at GS11,
b) two applications, (splits) in the seedbed (pre- crop emergence) and at GS 13, half the respective total at each timing
c) three applications, seedbed, GS13 and GS30, one third of the total at each timing.

All the above combinations were treated with or without a PGR programme, i.e.
1. Untreated, or
2. Moddus (trinexapac-ethyl) 0.2 l/ha GS30, followed by Terpal (mepiquat chloride plus ethephon) 0.5 l/ha, GS 39-45.

Variety: Optic

Results

1. Andover

Table 1. Yield (t/ha)

Nitrogen (kg/ha)	No. splits	PGR	2002	2003	2004	3 year mean
100	1	ut	5.77	7.05	6.62	6.48
100	2	ut	5.61	6.87	6.86	6.45
100	3	ut	5.18	6.82	6.21	6.07
100	1	Mod/Ter	5.46	7.04	6.54	6.35
100	2	Mod/Ter	5.83	6.97	6.55	6.45
100	3	Mod/Ter	5.56	6.60	6.51	6.22
150	1	ut	5.91	7.63	7.52	7.02
150	2	ut	5.96	7.54	7.55	7.02
150	3	ut	5.54	7.61	7.05	6.73
150	1	Mod/Ter	6.04	7.91	7.49	7.15
150	2	Mod/Ter	6.19	7.59	7.56	7.11
150	3	Mod/Ter	5.76	7.47	7.46	6.90
175	1	ut	5.70	7.81	7.27	6.93
175	2	ut	6.12	7.65	7.72	7.16
175	3	ut	5.67	7.92	7.28	6.96
175	1	Mod/Ter	5.97	7.90	7.21	7.03
175	2	Mod/Ter	6.23	8.01	7.84	7.36
175	3	Mod/Ter	5.95	8.07	7.65	7.22
200	1	ut	6.20	7.81	7.87	7.29
200	2	ut	6.00	7.82	7.92	7.25
200	3	ut	5.73	8.18	7.72	7.21
200	1	Mod/Ter	6.01	8.30	8.15	7.49
200	2	Mod/Ter	6.00	7.99	8.14	7.38
200	3	Mod/Ter	6.30	8.08	7.98	7.45
LSD (0.05)			*0.49*	*0.60*	*0.88*	

The three-year means indicate a yield penalty from splitting 100 kg/ha three ways. This effect is most apparent in the 2002 figures, and was smaller when PGR was applied, or when 150 kg/ha N was applied. There was no such effect of splitting with 175 or 200 kg/ha N. In 2002 there was a significant yield increase when PGR was applied to the 200 kg/ha, three split treatment (6.30 v 5.73 t/ha). Otherwise, there were no significant effects of PGR on the nitrogen timing responses. Overall there was no yield advantage in splitting the nitrogen, even when 200 kg/ha was applied. Yields tended to peak at the 150 kg/ha N level.

Table 2. Grain nitrogen (%)

Nitrogen (kg/ha)	No. splits	PGR	2002	2003	2004	3 year mean
100	1	ut	1.69	1.63	1.50	1.61
100	2	ut	1.52	1.60	1.44	1.52
100	3	ut	1.57	1.68	1.54	1.60
100	1	Mod/Ter	1.59	1.62	1.49	1.57
100	2	Mod/Ter	1.54	1.65	1.39	1.53
100	3	Mod/Ter	1.52	1.68	1.51	1.57
150	1	ut	1.62	1.73	1.61	1.65
150	2	ut	1.65	1.71	1.55	1.64
150	3	ut	1.50	1.81	1.58	1.63
150	1	Mod/Ter	1.65	1.73	1.56	1.65
150	2	Mod/Ter	1.62	1.70	1.50	1.61
150	3	Mod/Ter	1.53	1.81	1.62	1.65
175	1	ut	1.87	1.79	1.57	1.74
175	2	ut	1.70	1.75	1.59	1.68
175	3	ut	1.55	1.90	1.66	1.70
175	1	Mod/Ter	1.86	1.84	1.55	1.75
175	2	Mod/Ter	1.71	1.75	1.56	1.67
175	3	Mod/Ter	1.52	1.86	1.61	1.66
200	1	ut	1.80	1.84	1.75	1.80
200	2	ut	1.79	1.90	1.63	1.77
200	3	ut	1.58	1.92	1.67	1.72
200	1	Mod/Ter	1.90	1.90	1.76	1.85
200	2	Mod/Ter	1.76	1.83	1.63	1.74
200	3	Mod/Ter	1.61	2.01	1.62	1.75

In 2002, splitting clearly restricted the level of grain N, keeping the samples from the higher N rates within the target range. This effect was seen irrespective of whether a PGR treatment was applied. However, with the yields peaking at 150 kg/ha (see previous) there would have been little advantage in this, and with 100 kg/ha applied N, this reduction in grain N was a disadvantage, taking it below the target range. In 2003 and 2004, a similar trend was seen, but here the differences were smaller. The three-year means indicate a small but consistent reduction in grain N when two splits were applied rather than a single dose, though there is no consistent further benefit in splitting three ways. There was no consistent effect of PGR treatment on these nitrogen timing responses. Overall, the grain N levels were not excessive except at 200 kg/ha applied N, and with 150 kg/ha N also, splitting occasionally produced grain N below 1.65%.

Table 3. Screenings (% grain retained over 2.5mm sieve)

Nitrogen (kg/ha)	No. splits	PGR	2002	2003	2004	3 year mean
100	1	ut	87.1	95.9	96.9	93.3
100	2	ut	90.7	96.6	97.9	95.1
100	3	ut	91.6	96.7	96.9	95.1
100	1	Mod/Ter	91.5	97.1	97.0	95.2
100	2	Mod/Ter	92.1	96.8	97.6	95.5
100	3	Mod/Ter	91.2	96.6	97.1	95.0
150	1	ut	91.1	96.3	97.3	94.9
150	2	ut	88.9	96.7	96.7	94.1
150	3	ut	91.8	96.5	97.1	95.1
150	1	Mod/Ter	90.8	96.8	97.2	94.9
150	2	Mod/Ter	90.2	96.7	98.3	95.1
150	3	Mod/Ter	93.7	95.9	97.8	95.8
175	1	ut	83.4	96.4	97.3	92.4
175	2	ut	86.7	96.4	97.6	93.6
175	3	ut	89.7	96.5	97.4	94.5
175	1	Mod/Ter	85.0	96.9	96.3	92.7
175	2	Mod/Ter	87.0	96.9	98.1	94.0
175	3	Mod/Ter	92.1	95.3	97.4	94.9
200	1	ut	86.9	96.1	97.4	93.5
200	2	ut	87.0	95.8	97.3	93.4
200	3	ut	90.0	95.5	97.4	94.3
200	1	Mod/Ter	84.8	96.5	97.2	92.8
200	2	Mod/Ter	89.6	96.4	96.9	94.3
200	3	Mod/Ter	90.8	95.7	97.2	94.6

There was a tendency here for splitting to improve the % retention, particularly with the higher nitrogen rates. The biggest such effect was seen in 2002, which, as seen earlier (trial 1) was a poor year for screenings. Differences between treatments in 2003 and 2004 were very small.
Growth regulator treatment had no consistent effect on these responses.

2. Morley

Table 4. Yield (t/ha)

Nitrogen (kg/ha)	No. splits	PGR	2002	2003	2004	3 year mean
100	1	ut	7.65	8.25	4.58	6.83
100	2	ut	7.74	8.52	4.40	6.89
100	3	ut	7.64	8.07	4.47	6.73
100	1	Mod/Ter	7.93	8.36	4.77	7.02
100	2	Mod/Ter	8.08	8.28	4.52	6.96
100	3	Mod/Ter	7.84	8.48	4.61	6.98
150	1	ut	7.39	8.45	4.95	6.93
150	2	ut	7.95	8.50	4.57	7.01
150	3	ut	7.75	8.70	4.40	6.95
150	1	Mod/Ter	7.97	8.55	4.79	7.10
150	2	Mod/Ter	8.11	8.75	4.64	7.17
150	3	Mod/Ter	8.16	8.80	4.84	7.27
175	1	ut	7.31	8.86	4.61	6.93
175	2	ut	7.69	8.83	4.41	6.98
175	3	ut	7.71	8.62	4.64	6.99
175	1	Mod/Ter	7.84	8.87	4.82	7.18
175	2	Mod/Ter	8.09	8.84	4.52	7.15
175	3	Mod/Ter	8.06	8.85	4.96	7.29
200	1	ut	7.19	8.42	4.75	6.79
200	2	ut	7.47	8.57	4.78	6.94
200	3	ut	7.10	8.62	4.60	6.77
200	1	Mod/Ter	7.78	8.61	4.67	7.02
200	2	Mod/Ter	8.27	8.85	4.55	7.22
200	3	Mod/Ter	8.05	8.77	4.86	7.23
LSD (0.05)			*0.12*	*0.41*	*0.45*	

In 2002 there were significant yield increases to nitrogen splitting when any total N of 150 kg/ha or above was applied. However in the two later years there was little evidence of any response to nitrogen treatment, as is the case when the three-year means are considered. There were also significant yield responses to the PGR programme in 2002, for most of the nitrogen rate/timing combinations. This is again a reflection of the 2002 season, when unusual weather patterns affected the tillering of most spring barley crops.

In 2004 all yields were low, due to delayed establishment.

Table 5. Grain nitrogen (%)

Nitrogen (kg/ha)	No. splits	PGR	2002	2003	2004	3 year mean
100	1	ut	1.65	1.66	1.89	1.73
100	2	ut	1.54	1.56	1.81	1.64
100	3	ut	1.56	1.61	1.95	1.71
100	1	Mod/Ter	1.63	1.62	1.93	1.73
100	2	Mod/Ter	1.53	1.64	1.86	1.68
100	3	Mod/Ter	1.53	1.66	1.90	1.70
150	1	ut	2.00	1.79	2.04	1.94
150	2	ut	1.84	1.79	2.08	1.90
150	3	ut	1.90	1.88	2.05	1.94
150	1	Mod/Ter	1.89	1.83	2.08	1.93
150	2	Mod/Ter	1.77	1.84	2.05	1.89
150	3	Mod/Ter	1.83	1.86	2.09	1.93
175	1	ut	2.05	2.00	2.11	2.05
175	2	ut	1.97	1.91	2.11	2.00
175	3	ut	1.95	1.93	2.14	2.01
175	1	Mod/Ter	1.95	1.90	2.15	2.00
175	2	Mod/Ter	1.86	1.90	2.17	1.98
175	3	Mod/Ter	1.96	1.62	2.10	1.89
200	1	ut	2.13	2.04	2.16	2.11
200	2	ut	1.99	1.97	2.15	2.04
200	3	ut	2.09	2.00	2.16	2.08
200	1	Mod/Ter	2.14	1.99	2.15	2.09
200	2	Mod/Ter	1.99	1.97	2.19	2.05
200	3	Mod/Ter	2.04	2.00	2.15	2.06

The effects of splitting the nitrogen in 2002 reflect the higher yields, which have 'diluted' the grain N. In the other two years there are no consistent effects of splitting or PGR treatment on grain N.
In terms of total N response, the 175 and 200 kg/ha treatments have tended to produce grain N levels close to or above 1.85%. In 2004, when all yields were low, the grain N values are excessive for all treatments.

Screenings (% retention). There were no consistent treatment effects on screenings in any year for the Morley trial. The figures can be found in the appendix.

3. Perth

Table 6. Yield (t/ha)

Nitrogen (kg/ha)	No. splits	PGR	2002	2003	2004	3 year mean
100	1	ut	4.81	7.27	7.03	6.37
100	2	ut	5.32	8.02	6.92	6.75
100	3	ut	5.54	6.73	6.80	6.36
100	1	Mod/Ter	4.98	7.82	7.36	6.72
100	2	Mod/Ter	5.61	7.79	7.36	6.92
100	3	Mod/Ter	5.83	7.87	7.67	7.12
150	1	ut	5.93	8.25	7.67	7.28
150	2	ut	6.07	8.15	7.30	7.17
150	3	ut	5.94	8.10	7.56	7.20
150	1	Mod/Ter	5.71	8.13	8.06	7.30
150	2	Mod/Ter	6.01	8.32	8.05	7.46
150	3	Mod/Ter	6.27	8.58	8.19	7.68
175	1	ut	5.71	8.44	7.59	7.25
175	2	ut	6.40	8.38	7.20	7.33
175	3	ut	6.34	8.30	7.50	7.38
175	1	Mod/Ter	5.69	8.65	7.87	7.40
175	2	Mod/Ter	6.33	8.49	7.55	7.46
175	3	Mod/Ter	6.32	8.51	8.04	7.62
200	1	ut	6.06	7.91	7.31	7.09
200	2	ut	6.56	8.92	7.27	7.58
200	3	ut	6.48	8.48	7.48	7.48
200	1	Mod/Ter	5.83	8.39	7.32	7.18
200	2	Mod/Ter	6.35	8.71	7.84	7.63
200	3	Mod/Ter	6.40	8.10	7.60	7.37
LSD (0.05)			*0.47*	*0.83*	*0.47*	

In contrast to the results from the Andover site, here the 2002 figures show that splitting the lowest total N rate (100kg/ha) increased the yield. In other years the method of nitrogen delivery did not influence yield, nor did the total N applied. In 2004, the growth regulator treatment consistently improved the yield from all comparable N treatments, but this effect was not seen in 2003 or 2002.

Table 7. Grain nitrogen (%)

Nitrogen (kg/ha)	No. splits	PGR	2002	2003	2004	3 year mean
100	1	ut	1.68	1.53	1.57	1.59
100	2	ut	1.51	1.49	1.69	1.56
100	3	ut	1.55	1.43	1.55	1.51
100	1	Mod/Ter	1.60	1.50	1.56	1.55
100	2	Mod/Ter	1.40	1.47	1.55	1.47
100	3	Mod/Ter	1.57	1.46	1.60	1.54
150	1	ut	1.69	1.76	1.73	1.73
150	2	ut	1.75	1.67	1.72	1.71
150	3	ut	1.80	1.71	1.70	1.74
150	1	Mod/Ter	1.83	1.78	1.67	1.76
150	2	Mod/Ter	1.80	1.65	1.66	1.70
150	3	Mod/Ter	1.68	1.66	1.78	1.71
175	1	ut	1.99	1.90	1.81	1.90
175	2	ut	1.81	1.81	1.78	1.80
175	3	ut	1.82	1.61	1.81	1.75
175	1	Mod/Ter	1.99	1.85	1.79	1.88
175	2	Mod/Ter	1.81	1.79	1.81	1.80
175	3	Mod/Ter	1.89	1.79	1.78	1.82
200	1	ut	1.90	1.93	1.90	1.91
200	2	ut	1.92	1.85	1.77	1.85
200	3	ut	1.95	1.88	1.84	1.89
200	1	Mod/Ter	2.05	2.02	1.90	1.99
200	2	Mod/Ter	1.96	1.84	1.81	1.87
200	3	Mod/Ter	1.91	1.85	1.85	1.87

As in other trials, nitrogen rates above 150 kg/ha produced excessive grain N levels, and where the market is for grain N below 1.65%, then here 150 kg/ha was consistently excessive. In both 2002 and 2003, splitting reduced the grain N levels for a total N of 100 kg/ha, but had little effect on N totals above this. In 2004 there were no effects of splitting on grain N for any total N rate.

Again PGR had no consistent effect on grain N response to nitrogen treatment.

Table 8. Screenings (% retention over 2.5mm sieve)

Nitrogen (kg/ha)	No. splits	PGR	2002	2003	2004	3 year mean
100	1	ut	86.9	93.5	98.4	92.9
100	2	ut	91.9	94.6	97.0	94.5
100	3	ut	91.1	94.5	96.6	94.1
100	1	Mod/Ter	89.3	95.3	97.6	94.1
100	2	Mod/Ter	94.5	95.4	97.0	95.6
100	3	Mod/Ter	90.8	96.1	96.6	94.5
150	1	ut	91.5	90.4	97.1	93.0
150	2	ut	88.5	91.3	97.0	92.3
150	3	ut	87.9	91.0	95.5	91.5
150	1	Mod/Ter	85.4	92.1	97.1	91.5
150	2	Mod/Ter	88.8	94.1	96.6	93.2
150	3	Mod/Ter	90.8	94.1	95.4	93.4
175	1	ut	86.3	91.2	97.1	91.5
175	2	ut	89.2	90.2	97.2	92.2
175	3	ut	86.6	93.2	97.2	92.3
175	1	Mod/Ter	83.1	91.8	96.0	90.3
175	2	Mod/Ter	88.6	91.5	95.9	92.0
175	3	Mod/Ter	87.4	93.8	94.4	91.9
200	1	ut	90.3	89.0	96.8	92.0
200	2	ut	87.8	93.5	97.6	93.0
200	3	ut	88.7	89.8	97.5	92.0
200	1	Mod/Ter	83.1	88.0	96.8	89.3
200	2	Mod/Ter	85.0	90.4	96.2	90.5
200	3	Mod/Ter	87.2	90.5	93.4	90.4

The data for 2002 show the same effects seen in other trials in this year, with low retention figures resulting from high rates of nitrogen improved by the growth regulator sequence. A similar, but smaller, effect was seen in 2003, and no effect in 2004, again similar trends to those seen in other trials at this site.

Discussion

In the majority of cases, the optimum total nitrogen rate for yield was 150 kg/ha, as in other trials within this project. At this level of N there were few cases where the total needed to be applied in more than one application.
Occasionally, splitting restricted the grain nitrogen content with higher applied N doses, (Andover 2002, Perth 2003) but again, with yields peaking at 150kg/ha N this would have little practical significance. There are also examples where splitting reduced yield with the lowest applied N rate, (Andover 2002, Morley 2003), and at these sites a similar effect on grain nitrogen brought this well below the target range.
However, in 2002 at Andover, this effect on grain nitrogen produced values within the 1.65-1.85% target range with 200 kg/ha applied N, but again this was not the optimum rate for yield.

Unfortunately this reduction in grain nitrogen was not seen as clearly in the Perth trials, where such an effect would have been beneficial in reducing grain N from higher rates of applied nitrogen, thereby achieving higher yield but satisfying the market for low grain N which dominates in that area.

At Andover and Morley, where the reduction in yield from splitting low rates of applied N were seen, there was also evidence that a growth regulator programme prevented this. Again, however, this effect was not seen with 150 kg/ha applied N, which tended to give the optimum yield and grain nitrogen level.

The screenings, or % retention, figures for Andover indicate that splitting the nitrogen improved retention in 2002, (the year previously identified as one where screenings were high due to excessive fertile tiller retention) in the same way that growth regulators improved retention as seen in trial 1 (qv). This PGR effect is not as clear in this trial, but splitting the nitrogen may be another way of moderating tiller numbers when these are likely to be excessive. As in trial 1, these effects were not seen in 2003 and 2004 , when % retention was close to or within the required threshold, nor in 2002 at Morley or Perth.

With higher rates of applied nitrogen, therefore, or where screenings were high, there were benefits in splitting the nitrogen and in the use of growth regulators. However one should look at the rate of applied N that gave the optimum yield and grain N, and then decide if splitting was beneficial. In these trials this rate was usually 150 kg/ha N, and with this rate the effects of splitting and of growth regulators were inconsistent. In fact, with the 100 kg/ha rate of N, and occasionally with 150 kg/ha, splitting actually reduced yield.

Therefore this trial has demonstrated benefits from splitting the total nitrogen applied to the crop, but only at applied N rates which would not be cost-effective to use, and at the optimum N rate (150 kg/ha) there were no yield or quality disadvantages in applying all the nitrogen in one dose at early crop emergence.

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Appendix

Trial 2 Caythorpe

Screenings (% retention over 2.5mm sieve) cv Optic

Nitrogen (kg/ha)	Seed rate/m^2	PGR	2002	2003	2004	3 yr mean
100	200	None	91.1	95.9	98.1	95.0
100	200	Moddus/Terpal	92.5	96.5	98.5	95.8
100	300	None	91.9	96.4	98.6	95.6
100	300	Mod/Ter	91.9	96.7	98.6	95.7
100	400	None	93.2	97.1	98.2	96.2
100	400	Moddus/Ter	95.0	96.3	98.8	96.7
175	200	None	91.6	97.1	98.1	95.6
175	200	Mod/Ter	92.0	96.2	98.8	95.7
175	300	None	92.1	96.7	98.3	95.7
175	300	Mod/Ter	92.8	96.5	98.3	95.9
175	400	None	89.0	96.8	98.5	94.8
175	400	Moddus/Ter	94.6	95.9	98.9	96.5

Trial 3. Morley

Screenings (% retention over 2.5mm sieve) cv Optic

Nitrogen (kg/ha)	No. splits	PGR	2002	2003	2004	3 year mean
100	1	ut	91.4	97.2	98.6	95.7
100	2	ut	91.6	98.2	98.0	95.9
100	3	ut	91.0	97.2	98.3	95.5
100	1	Mod/Ter	93.8	96.6	98.5	96.3
100	2	Mod/Ter	94.5	97.1	97.9	96.5
100	3	Mod/Ter	93.1	95.9	97.6	95.5
150	1	ut	83.3	95.6	98.1	92.3
150	2	ut	84.4	96.2	96.8	92.5
150	3	ut	85.4	95.4	97.0	92.6
150	1	Mod/Ter	90.0	97.0	97.9	95.0
150	2	Mod/Ter	91.7	97.2	97.6	95.5
150	3	Mod/Ter	89.6	96.4	97.9	94.6
175	1	ut	84.6	93.9	97.7	92.1
175	2	ut	86.1	94.9	97.3	92.8
175	3	ut	82.4	95.3	97.1	91.6
175	1	Mod/Ter	87.8	96.6	97.3	93.9
175	2	Mod/Ter	90.8	94.6	97.3	94.2
175	3	Mod/Ter	87.8	94.9	97.8	93.5
200	1	ut	81.5	94.1	96.6	90.7
200	2	ut	85.4	94.7	95.9	92.0
200	3	ut	81.0	93.6	96.3	90.3
200	1	Mod/Ter	89.3	96.3	97.7	94.4
200	2	Mod/Ter	89.6	94.9	96.9	93.8
200	3	Mod/Ter	87.9	94.8	97.7	93.5