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Review of how best to respond to expensive fertiliser nitrogen for use in 2022 (part three – oats)

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CONTENTS

1. Abstract

This report examines whether the wheat and barley findings described in earlier parts of this study are appropriate for winter and spring oats. In particular, the study outlines how oat growers can best respond to current prices and availability of manufactured fertilisers.

After describing conventional methods for determining nitrogen optima (from results of experiments with fertiliser nitrogen on oat yields), responses to fertiliser nitrogen in recent experiments –12 on winter oats and 12 on spring oats – are compared with the standard responses used to determine current price adjustments in RB209.

It was concluded that the extended RB209 adjustment table, which was deemed appropriate for winter wheat and winter and spring barley, is not satisfactory for winter and spring oats. Therefore, adjustments were made to the parameters for the nitrogen adjustment curve – which more appropriately fitted the data from the recent experiments considered – and a new extended adjustment table made.

Economic optimum amounts of fertiliser nitrogen decrease as the break-even price ratio (BER) between grain and fertiliser nitrogen increases. Current RB209 recommendations were devised for a BER of 5 kg cereal grain to 1 kg nitrogen and RB209 tables for BER adjustments extended to an nitrogen price of £1.40/kg. As recent prices of nitrogen fertiliser have reached £2.00/kg (and may go higher), the RB209 tables have been extended here up to £2.50/kg nitrogen. As cereal grain prices are also strong, tables have been extended to prices of £350/tonne.

The revised tables, based on the new curve parameters for oats, indicate that if grain prices were £200/tonne, the optimal change in use of ammonium nitrate fertiliser, due to doubling its price from £345 (BER=5) to £690/tonne (BER=10), is to reduce its use by 25 kg/ha on both winter and spring oats. Effects on yields would be relatively small, around -0.2 t/ha.

However, prices for milling oats are currently around £180/tonne, creating a BER closer to 11 at the current price of ammonium nitrate at £690/tonne. Using the new nitrogen adjustment information, a grain sale price of £175/tonne and ammonium nitrate price of £690/tonne would relate to a recommendation of reducing nitrogen usage by 30 kg/ha, relating to an average yield loss of 0.26 t/ha. The reductions to nitrogen recommended with increasing BER described here for oats are less than those advocated for other cereals in the earlier parts of this study.

Although oat yields may be slightly reduced with less nitrogen applied, it is unlikely that there would be detrimental effects on specific weight or screenings.

2. Introduction

This is the third part of a three-stage review of how the arable cropping industry can best respond to the recent sharp increases in prices and availability of manufactured fertilisers.

Part one addressed how nitrogen rates should be changed in response to increases in nitrogen fertiliser prices and the impact of these changes on crop yield for the major arable crops – wheat, barley and oilseed rape. In addition to the report (Sylvester-Bradley and Kindred, 2021), this resulted in the AHDB online calculator, which farmers can use to estimate the impact of nitrogen fertiliser prices on nitrogen rate and yield.

Part two, building on part one, assessed the impact on other aspects of fertiliser management. It covered which crops, fields and nitrogen splits to prioritise; the influence of expected yield; any implications for management of organic materials; achieving milling and malting specification; the value of precision nitrogen use; calculating the nitrogen price; the management of other nutrients; and longer-term implications.

Part three, this report, examines whether the wheat and barley findings are appropriate for the oats sector and, if not, how oats growers can best respond to the current prices and availability of manufactured fertilisers. Both winter and spring oats crops are considered.

2.1. Recent trends in prices of fertilisers and crop produce

Associated with sharp increases in energy prices during 2021, and with limits on availability of natural gas, prices of manufactured N fertilisers have increased, and their availability for on-farm delivery has reduced.

Farmers and farm suppliers need guidance on how best to respond to these changes; their main concerns are to know whether, and by how much, they should reduce the rates of fertiliser N that they normally apply, and by how much this will reduce their crop yields.

The fertiliser experiments that have habitually been conducted on the major arable crops since the use of manufactured fertilisers began have regularly been reviewed in order to support farmers' decision-making on fertiliser use, and recommendations have been produced and regularly revised accordingly, currently published as the AHDB Nutrient Management Guide (RB209; AHDB, 2016).

2.2. What the Nutrient Management Guide (RB209) states

The current (2022) version of the AHDB Nutrient Management Guide (RB209) includes Table 4.22 to show how N recommendations for cereals should be adjusted for changes in prices of fertiliser or grain. This table was introduced in the 8th edition of RB209 (Defra, 2010 page 106) from experimental evidence collated up to 2008; their content has not been revised since AHDB took responsibility for RB209. The table was produced assuming the shape of the crop response around the optimum rate of fertiliser N is the same for all cereals.

This table no longer addresses the current and expected range of prices for grains and fertilisers, so were extended in Phase 1 of the review, and effects on crop yields were tabulated.

It is possible that with changes in varieties, and with further evidence since these tables were included in the 9th Edition of RB209 (AHDB, 2016), the assumption of a standard response shape for all cereals needs to be changed. In Phase 1 of the review, these curves were re-examined using recent evidence (Sylvester-Bradley and Kindred, 2021). It was found that the extended adjustment tables are satisfactory for winter wheat, and adequate for winter and spring barley at present.

However, further consideration should be given to whether a different assumption of a standard response shape is needed for oats compared to other cereals. At the 2016 review of RB209 there were insufficient winter or spring oats data to make robust conclusions.

Section 3 of this report therefore shows how N optima are defined and Section 4 shows how response curves from recent experiments on oat yields in response to varying N application rates compare with the standard response in all cereals assumed in RB209 at present.

3. Defining economic optimum fertiliser use

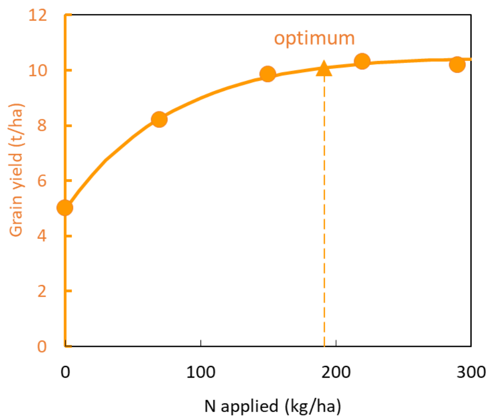
The purpose of this section is to describe how crops respond to fertiliser N, to show how economic optimum amounts of fertiliser N are determined from experimental evidence, and to explain how price changes affect these economic optima.

3.1. Summarising multi-level fertiliser experiments

Response experiments have been conducted on arable crops since World War II and before (Crowther & Yates 1941). Results show huge variability in fertiliser effects, but they predominantly show that the applications of fertiliser N increase crop yields with diminishing increments in yield with each additional N increment. To interpret these experiments, it is necessary to find a way of interpolating crop effects between the amounts of fertiliser that were tested. This is done by statistically fitting algebraically defined response curves to the yield data.

3.1.1. **Response curves**

After much debate through the 1960s and 1970s about the most appropriate form of response curve to use to describe yield responses to N, the linear plus exponential (LpE) function was adopted for derivation of the government's fertiliser recommendations for all combinable crops (George, 1984). [Note that a two split line function was adopted for sugar beet (Jaggard *et al.*, 2009).] Current approaches to curve fitting are described in detail by Sylvester-Bradley *et al.* (2014).



The LpE function takes the form:

$$y = a + b \times r^N + c \times N$$

where y is the yield in t/ha at 0.85 g/g DM, N is the total fertilizer N applied (kg/ha), and a, b, c and r are parameters determined by statistical fitting.

3.1.2. **Determination of the optimum**

The economic optimum (Nopt) is defined as the point at which the value of extra grain produced ceases to exceed the cost of the extra N applied. Nopt can be determined from parameters from the LpE function as follows:

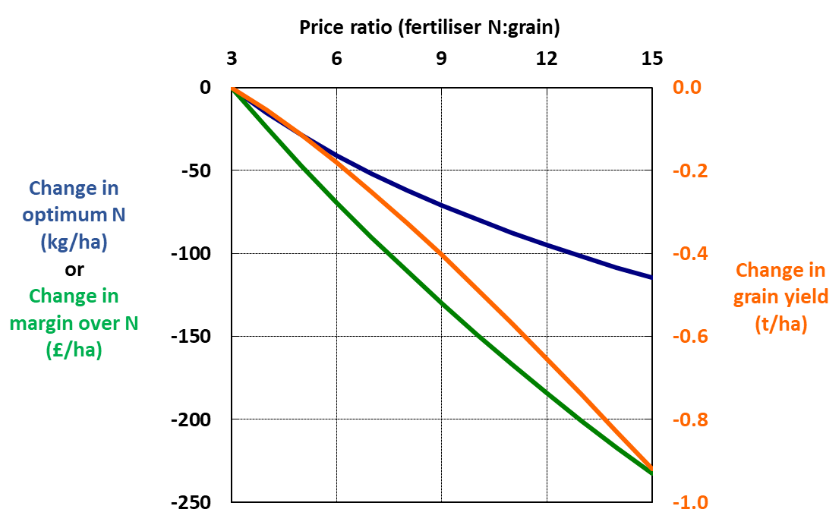
$$Nopt = [Ln\{(P/1000 - c)/(b \times Ln\ r)\}]/Ln\ r$$

where P is the price ratio of N (£/kg) to grain (£/kg) or 'Break-Even Ratio' (BER), taken in the current version of RB209 as five. It is important to note that determination of Nopt does not depend on the 'a' parameter from the LpE function; it only depends on the b, c and r parameters.

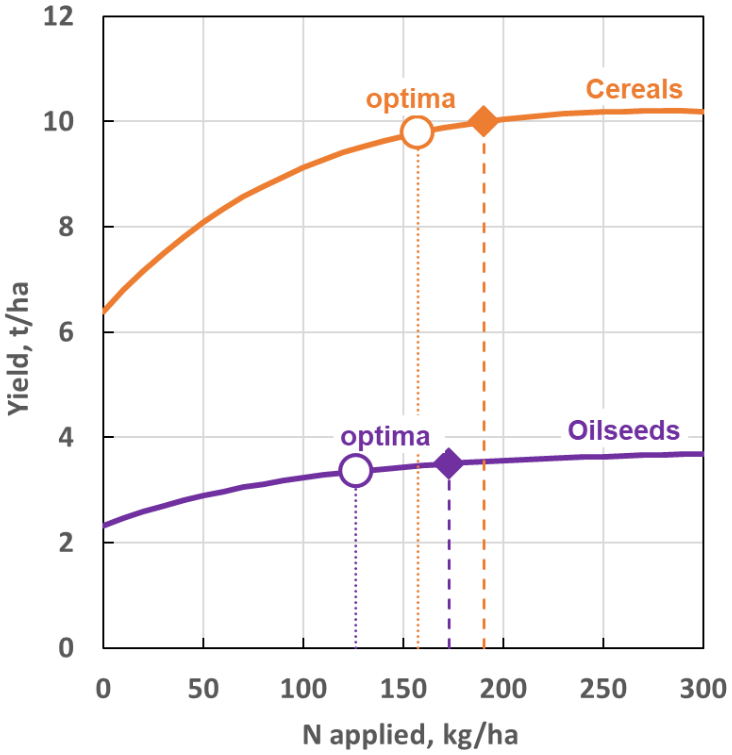
The optimum yield (Yopt) at Nopt can then be determined by using the Nopt value in the LpE function above.

3.1.3. **The break-even ratio (BER)**

The BER increases as fertiliser prices increase and decreases as grain prices increase. Over the decades both have tended to vary together, so the BER used in fertiliser recommendations remained set at 3:1 from the inception of recommendations in 1967 until the 8th Edition of RB209 was published in 2010 when it was increased to 5:1.



As the BER increases, Nopt, Yopt and the margin of grain value over N cost all decrease (Fig. 3.2). However, the extent to which they decrease depends on the shape of the response to N, as described by the LpE function. The most influential LpE parameter on these effects is 'r', the next most influential is 'c', and the least is 'b', noting that the 'a' parameter has no influence at all. Thus, if the response to N is fairly 'flat' as for oilseeds (Fig. 3.3) the effect of a change in BER from say 5 to 8 will be larger than if the response to N changes 'sharply' i.e. over a small range of N applied as for cereal in Fig. 3.3.



3.1.4. **Variation in N responses**

Most of the large variation in N responses and N optima is seen to be reflected in the values of the ‘a’ and ‘b’ parameters of the LpE function; much less variation is seen in the ‘c’ and ‘r’ parameters. Thus, the shapes of N responses are much less variable than their asymptotes and their intercepts.

The main factors seen to affect the shapes of yield responses to N are site and crop species. Most of the many experiments comparing varieties have found that allowing different values for the ‘r’ parameter between varieties is not justified.

However, it is to be expected that experiments where high N amounts reduce crop yields (through increased lodging or disease) will show a sharper change in N responses than experiments where little or no lodging occurs.

Thus, the prime question addressed here is whether, after a recent focus of experimentation on non-wheat cereals, especially on barleys which are more prone to lodging than wheats, there might be sufficient evidence to recommend different adjustments for changes in BER than are currently provided in RB209.

4. Recent oat responses

To determine whether adjustments to N recommendations for cereals in the current version of RB209 are still appropriate for oats, this section presents N response curves collated from more recent experiments on winter and spring oats (Table 3.1) and compares them with the standard response curves used.

4.1. Recent winter and spring oats data sources

This analysis comprised UK and Irish winter and spring oats N response data from 2009 to 2021, although the majority had been carried out since the last analysis of RB209 in 2016. The experiments were carried out as part of AHDB projects InnovOat (AHDB ref. 2200002) and NoatS (AHDB ref. 21140039) or were contributed by collaborators (Teagasc, PepsiCo, IBERS, Jordans, KWS) as part of these projects.

Some experiments included factorial comparisons with N timings, varieties, or other nutrients. It was generally found that differences in shape of responses were mainly between site-seasons (rather than within site-seasons) i.e., curves fitted to a series of varieties all compared within the same trial (site-season) had the same or very similar ‘c’ and ‘r’ parameters for the LpE function. To avoid an impression of spurious precision in the evidence base for the crops where multiple varieties were being tested only one representative response curve was selected from each site-season for this review.

Table 3.1: Datasets used to inform adjustments

Crop type	Winter oats	Spring oats
No. of N Response trials included	12	12

These selected responses are reported overleaf.

4.2. Winter oats

When the recent winter oats curves were collated (Fig. 3.1), it could be seen that the median of the curves does not coincide with the RB209 standard curve for cereals. Because of this, there will be imprecision resulting from using the RB209 adjustment table, becoming significant when the deviation from Nopt at BER 5 is not far from zero adjustment. Therefore, a new standard curve, shown in red, was created to fit the median results more closely.

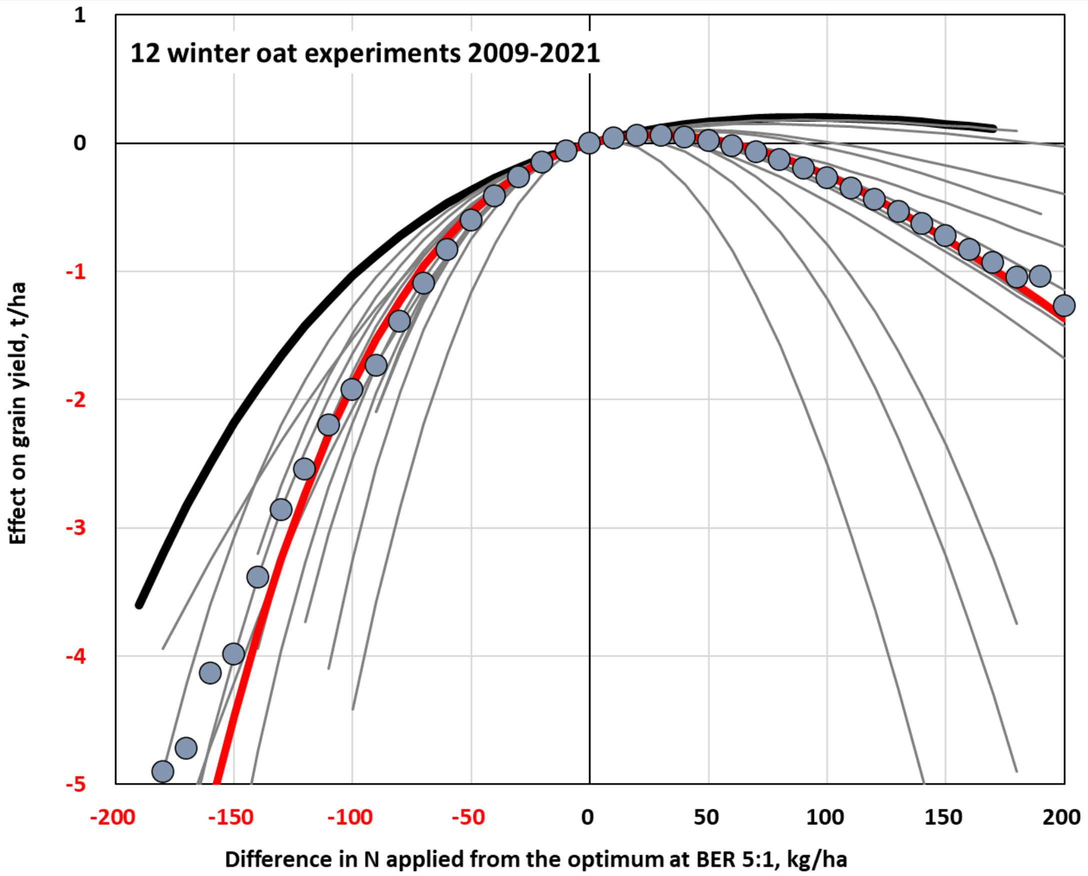


Figure 3.1: Effects on grain yield of altering N applied from the optimum amount at a break-even ration (BER) of 5:1 kg grain per kg N for (i) N response curves (fine grey lines) fitted to yield data from 12 winter oat experiments conducted between harvest 2009 and harvest 2021, (ii) their median (grey circles), (iii) the standard response curve (bold black line) used to adjust N recommendations in Table 4.22 of RB209 since 2008 and (iv) the new suggested response curve (bold red line) adjusted for recent N response data.

4.3. Spring oats

As per the winter oats, the median of recent spring oats experiments did not coincide with the RB209 standard curve for cereals. The same new standard curve created for winter oats is also presented on this graph in red, which also closely fits the results from the recent N response experiments on spring oats.

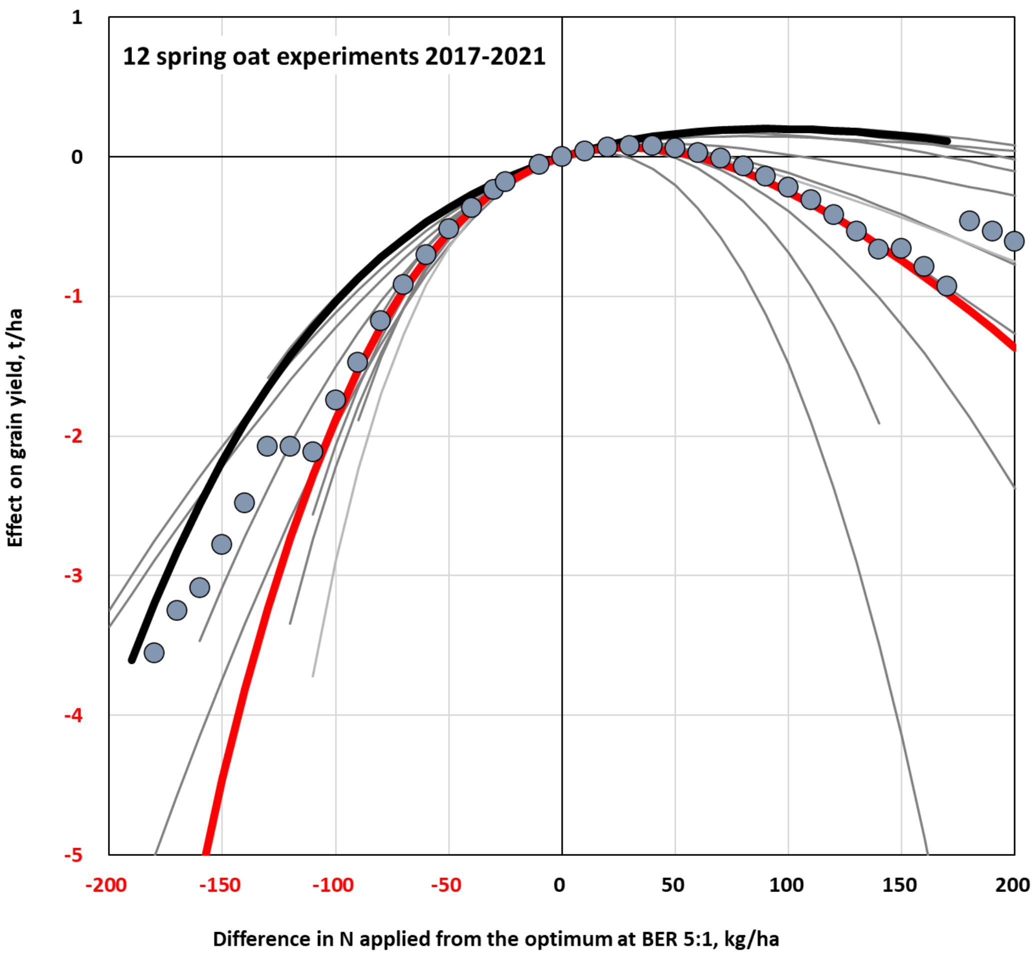


Figure 3.2: Effects on grain yield of altering N applied from the optimum amount at a break-even ration (BER) of 5:1 kg grain per kg N for (i) N response curves (fine grey lines) fitted to yield data from 12 spring oat experiments conducted between harvest 2017 and harvest 2021, (ii) their median (grey circles), (iii) the standard response curve (bold black line) used to adjust N recommendations in Table 4.22 of RB209 since 2008 and (iv) the new suggested response curve (bold red line) adjusted for recent N response data.

5. New adjustments for oats

he parameters of the new oats standard curve illustrated in Figures 3.1 and 3.2 were used to calculate the adjustments that should be made to N recommendations for oats.

5.1. Adjustments for N recommendations

Table 4.1 shows the adjustments to N recommendations from RB209 that should be made at different fertiliser and grain price combinations. Compared to the table created in Phase 1 of the study for wheat and barley, this table shows that more modest adjustments should generally be made for oats.

Table 4.1: New version of the extended version of Table 4.22 in RB209 to embrace new recommendations for oats and current prices and trends for cereals.

Nitrogen source	Fertiliser nitrogen content	Fertiliser cost								
	%	£/tonne product								
Ammonium Nitrate	34.5%	£173	£259	£345	£431	£518	£604	£690	£776	£863
Urea	46.0%	£230	£345	£460	£575	£690	£805	£920	£1,035	£1,150
Urea-Ammonium Nitrate Liquid	28.0%	£140	£210	£280	£350	£420	£490	£560	£630	£700
Cost of fertiliser nitrogen	*£/kg N*	£0.50	£0.75	£1.00	£1.25	£1.50	£1.75	£2.00	£2.25	£2.50
	Grain sale price	Change to recommendation for OATS								
	£/tonne	kg/ha N								
	50	-25	-40	-60	-70	-85	-95	-105	-115	-125
	75	-10	-25	-35	-45	-60	-65	-75	-85	-90
	100	0	-10	-25	-30	-40	-50	-60	-65	-70
	125	5	-5	-15	-25	-30	-40	-45	-50	-60
decrease	150	10	0	-10	-15	-25	-30	-35	-40	-45
increase	175	10	5	-5	-10	-15	-25	-30	-35	-40
	200	15	5	0	-5	-10	-15	-25	-30	-30
	225	15	10	5	-5	-10	-15	-20	-25	-25
	250	15	10	5	0	-5	-10	-15	-20	-25
	275	15	10	5	0	0	-5	-10	-15	-20
	300	20	15	10	5	0	-5	-10	-10	-15
	325	20	15	10	5	0	0	-5	-10	-15
	350	20	15	10	5	5	0	-5	-5	-10

The table above are provided in the same format as is used in the AHDB Nutrient Management Guide (RB209). However, for users who are more familiar with calculating their own BERs, it is also possible to present the same information in a more efficient graphical format (Fig. 4.1).

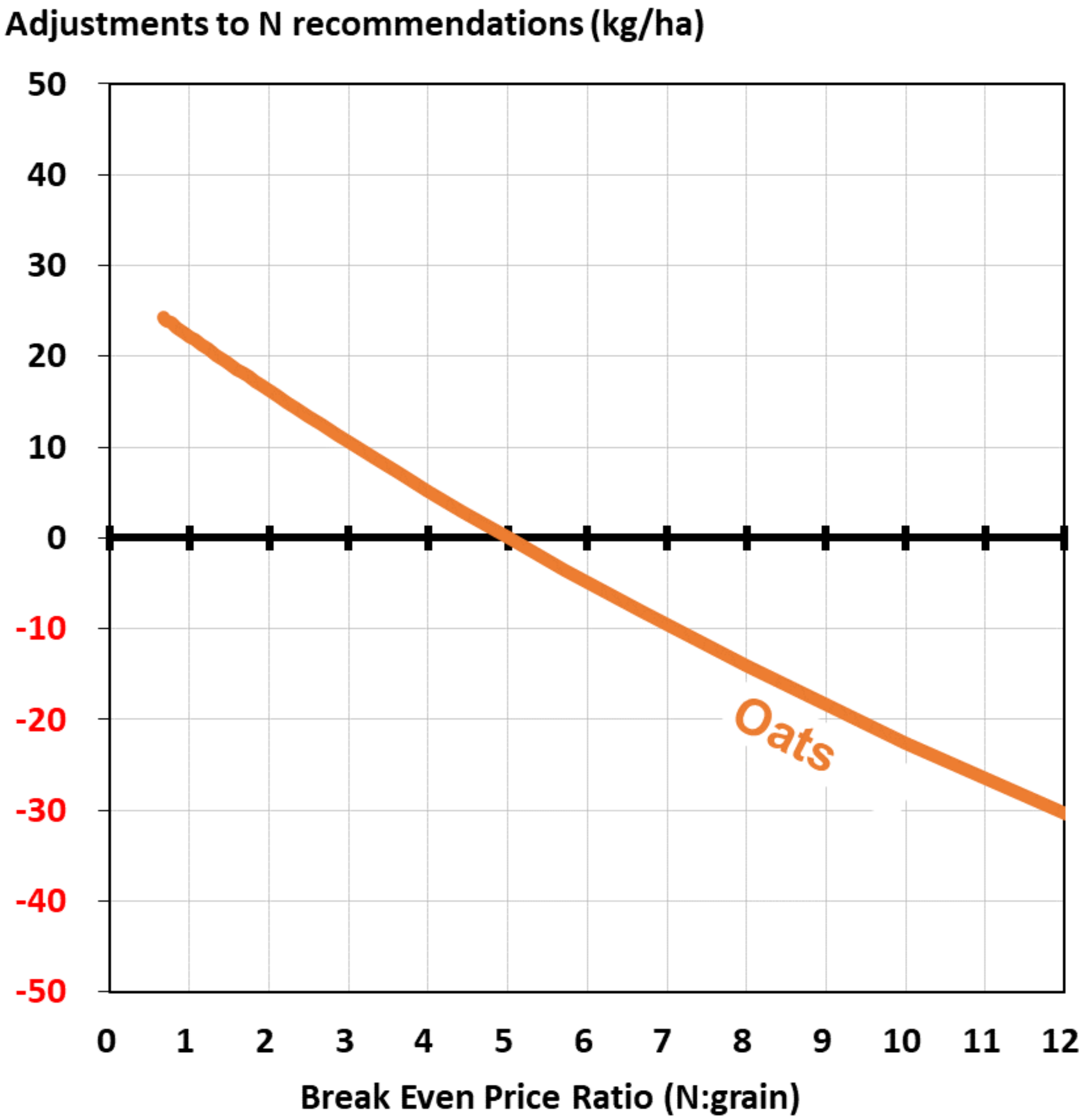


Figure 4.1: How adjustments to fertiliser N recommendations presented in Table 4.1 relate to the Break-Even price Ratios for oats.

5.2. Yield effects

Whilst adjustments to recommendations set out in Section 5.1 will maximise the margin over fertiliser cost, they will also cause decreases in grain production. These have been estimated in Table 4.2 using the same response functions as in Table 4.1.

Table 4.2: Effect on grain yield of adjusting N applied from the optimum at a break-even price ratio of 5 kg grain per kg N for oats.

	OATS
Reduction in N applied (kg/ha)	Effect on yield (t/ha)
0	0
-10	-0.06
-20	-0.15
-30	-0.26
-40	-0.41
-50	-0.59
-60	-0.81
-70	-1.07
-80	-1.35
-90	-1.68
-100	-1.93

5.3. Potential impacts on grain quality

When growing oats for milling, achieving quality specifications, particularly a specific weight of over 50 kg/Hl, is key. With reductions in the amount of N applied to oats and a potential reduction in yield, as illustrated above, there may be a concern that quality could be affected.

Recent work in the AHDB InnovOat and NoatS projects investigating the effects of changes in N rate on oats grain quality generally shows that reductions in N do not detrimentally affect specific weight. Indeed, specific weights are usually maintained, or sometimes higher, at lower N rates in certain varieties. The same trials also generally showed a reduction in screenings at lower N rates. The opposite effect was found for kernel content, however; lower N rates appear to lead to lower percentage kernel contents. Figure 4.2 shows responses of: a) specific weight; and b) kernel content, to increasing N rates in three different varieties. These results were from one winter oats trial in 2021 but are typical of responses seen in other experiments.

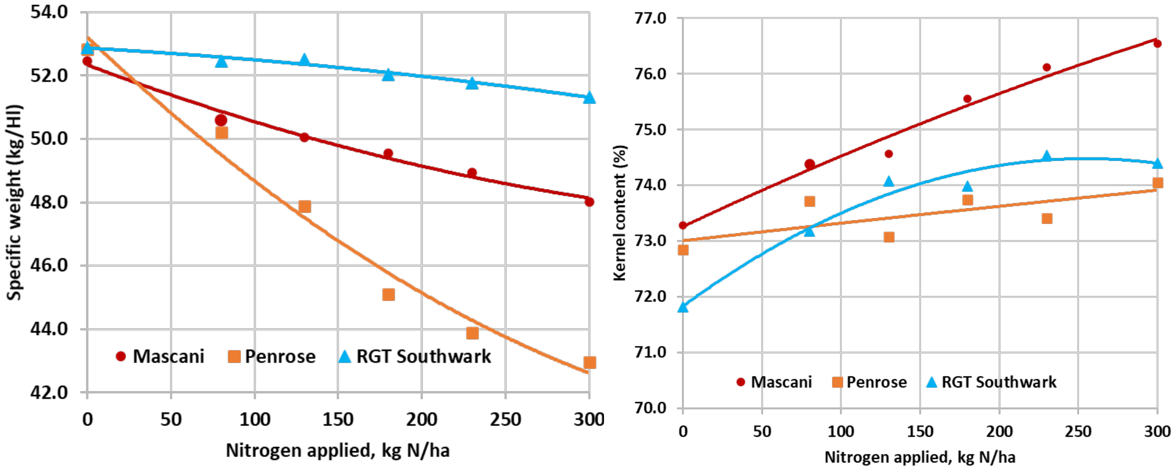


Figure 4.2: The effect of nitrogen rate on a) specific weight and b) kernel content in three winter oats varieties (Mascani, RGT Southwark and Penrose). Data are from an experiment carried out as part of the AHDB funded NoatS project (21140039) in 2021.

5.4. Which splits to prioritise

The current RB209 recommendations for timing of N for winter oats are as follows:

- Less than 100 kg N/ha: Apply as a single dressing by early stem extension, but not before late March
- 100 kg N/ha or more: Split the dressing, with 40 kg N/ha in mid-February/ early march
    - If the remaining N is less than 100 kg N/ha, then apply the rest by early stem extension but not before late March
    - If the remaining N is 100 kg N/ha or more, then apply in two dressings, half at early stem extension (not before late March) and half at least two weeks later

These recommendations assume appropriate measures are taken to control lodging (e.g. choice of variety or use of plant growth regulator). Reduce the recommended rate by 40 kg N/ha if lodging risk is high.

If the total N rate is reduced below the rate currently recommended in RB209 (i.e. for a BER of 5), the rate at each split should be reduced by the same proportion. However, if the crop has a low shoot number the first split should be maintained at a similar level as would have been used before any reduction in N rate to account for a high BER.

There is currently no advice in RB209 as to the most appropriate N timings for spring oats. This knowledge gap is being addressed in the current AHDB NoatS project which is due to report in May 2022. However, the same principles apply as with winter oats described above.

6. DISCUSSION

The new evidence assembled here: (i) 12 experiments on winter oats and (ii) 12 on spring oats, appears to justify different adjustments to N recommendations for oats compared to other cereals. The 'standard RB209' response curve used to determine the cereal adjustments did not relate well to the median response curves for oats.

Differences between the standard RB209 curve and the new curve suggested from this research is a result of oat yields responding more extremely to both increased and decreased N applications from the optimum rate, with greater yield penalties of that predicted by the standard curve used for all cereals. In oats, higher than optimal N rates often result in lodging and consequently a reduction in yield. The response curves showed relatively small increases or decreases in N applied can have a larger effect on yield than would be seen in wheat.

The new tables based on the new curve parameters in Section 4 indicate that, if grain prices were £200/tonne, the optimal change in use of ammonium nitrate fertiliser, due to doubling its price from £345 (BER=5) to £690/tonne (BER=10), is to reduce its use by 25 kg/ha on both winter and spring oats. Effects on yields would be relatively small, around -0.2 t/ha (Table 4.2).

However, prices for milling oats are currently ~£180/tonne, creating a BER closer to 11 at the current price of ammonium nitrate at £690/tonne. Using the new N adjustment information in Table 4.1, a grain sale price of £175/tonne and ammonium nitrate price of £690/tonne would relate to a recommendation of reducing N usage by 30 kg/ha, relating to an average yield loss of 0.26 t/ha. The reductions to N recommended with increasing BER found here for oats are less than those advocated for other cereals in the first part of this study.

Although oat yields may be slightly reduced with less N applied, it is unlikely that there would be detrimental effects on specific weight or screenings.

7. References

AHDB (2016) *The Nutrient Management Guide (RB209).* Accessed here Feb 2022.

Berry, P.M. & Spink, J.H. (2009). 'Canopy management' and late nitrogen applications to improve yield of oilseed rape. AHDB Project Report 447. Pp. 211. Accessed here Nov 2021.

Crowther, E. M. & Yates, F. (1941). Fertilizer policy in wartime. The fertilizer requirements of arable crops. *Empire Journal of Experimental Agriculture* **9**, 77-97.

Defra (2010). *Fertiliser Manual (RB209). 8th Edition.* The Stationery Office, Norwich. Pp. 253

George, B. J. (1984). *Design and interpretation of nitrogen response experiments.* In *The Nitrogen Requirement of Cereals*. MAFF Reference Book 385, pp. 133–149, London: HMSO.

Jaggard, K.W. Qi, A. & Armstrong, M.J . (2009). A meta-analysis of sugarbeet yield responses to nitrogen fertilizer measured in England since 1980. *Journal Of Agricultural Science* **147**, 287–301.

Kendall, S., Holmes, H.F. & Berry, P.M. (2017). *Updating N fertiliser management guidelines for winter barley*. AHDB PR 571, pp. 87 Accessed here Nov 2021.

Kendall, S.L., Fitters, T.F.J., Berry, P.M., Hoad, S.P. & Bingham, I.J. (2021). Updating nitrogen and sulphur fertiliser recommendations for spring barley. AHDB PR 635. Pp.188. Accessed here Nov. 2021.

Kindred, D.R., Clarke, S.M., Sylvester-Bradley, R., Hatley, D., Roques, S., Morris, N., Knight, S., Langton, D. & Blake-Kalff, M.A. (2018). *Using farm experience to improve N management for wheat (LearN)* AHDB Project Report No. 596, Pp.82. Accessed here Nov. 2021.

Roques, S. Berry, P., Knight, S., Morris, N., Clarke, S. & Sagoo, L. (2016). *Review of evidence on the principles of crop nutrient management and nutrition for cereals and oilseeds.* AHDB Research Review No. 3110149017, Pp. 66.

Sylvester-Bradley, R., Kindred, D.R., Wynn, S.C., Thorman, R.E. & Smith, K.E. (2014). Efficiencies of nitrogen fertilizers for winter cereal production, with implications for greenhouse gas intensities of grain. *The Journal of Agricultural Science* **152**, 3-22. Available on CJO doi:10.1017/S0021859612000810.

—Sylvester-Bradley, R., Kindred, D.R., Berry, P.M., Storer, K., Kendall, S. & Welham S. (2015) Development of appropriate testing methodology for assessing nitrogen requirements of wheat and oilseed rape varieties. Defra Report IF01110, Pp. 77. Accessed here Nov 2021