Predicting the optimum rate and timing of nitrogen fertiliser for winter oilseed rape

P.M. Berry. ADAS High Mowthorpe, Duggleby, Malton, North Yorkshire, YO178BP, UK.

Abstract

This paper describes and tests a method for predicting how much nitrogen (N) fertiliser to apply to winter oilseed rape. The prediction methodology, known as 'Canopy Management', assumes that an optimum sized canopy must be grown by flowering and that additional N is required for high yielding crops. The Canopy Management method was tested against data from nine experiments and was shown to give a good prediction of fertiliser N requirement. The experiments also showed that the first application of N fertiliser should be delayed until after the green bud stage (GS3,5) for crops with a large green area index of 1.5 or above following winter.

Background

Nitrogen (N) fertiliser commonly doubles oilseed rape yields, but is usually the most expensive crop input, is responsible for approximately 70% of greenhouse gas emissions associated with oilseed rape production as well as affecting the risk of nitrate leaching. Accurate prediction of N fertiliser requirement, together with optimal application timings, are therefore important for maximising profits and minimising pollution. Several factors affect the crop's requirement for N fertiliser including the amount of available N in the soil, the amount of N taken up by the crop before N fertiliser is applied and the yield potential of the crop. This paper describes and tests a method for predicting how much N fertiliser to apply to winter oilseed rape that takes all these factors into account, and investigates the optimum time to apply N.

Method for predicting fertiliser N requirement

This section describes a set of principles which can be used to predict N fertiliser requirement and which together are referred to as 'Canopy Management'. Previous research has demonstrated that winter oilseed rape must achieve an optimum green area index (GAI) of 3.5 units at flowering (Lunn *et al*., 2001). Larger canopies set fewer seeds/m^2 and are more prone to lodging, whilst smaller canopies do not intercept all of the available light. It has been shown that the crop must take up 50 kg N/ha to build each unit of GAI (Lunn *et al*., 2001). The Canopy Management principles therefore assumed that the crop must take up 175 kg N/ha by flowering to achieve the optimum GAI of 3.5. It was assumed that any N that the crop had taken up by the end of winter remained in the crop until flowering and therefore contributed to the production of the optimum GAI. It was assumed that oilseed rape took up 100% of the soil mineral N measured in February and 60% of any fertiliser N applied (55% on shallow soils over chalk or limestone). These N uptake efficiencies are similar to average figures that have been measured in wheat (Stokes *et al*., 1997; Vadyanathan *et al*. (1987). Holmes and Ainsley (1979) and unpublished datasets have shown that the economic N rate increases by 50-60 kg N/ha for each additional tonne per hectare in yield. It is assumed here that crops require 60 kg/ha more fertiliser N for each additional tonne in potential yield above 3.5 t/ha than required to build an optimum sized canopy. Fertiliser N required to achieve the optimum sized canopy was applied as late as possible whilst allowing time for the crop to take up the N by flowering (assuming an N uptake rate of 3 kg/day). Fertiliser N required for high yield was applied at early flowering to minimise the chance of growing a super-optimal canopy.

Experimental methods

Nine N response experiments carried out in harvest years 2006, 2007 and 2008 have been used to develop and test the method for predicting the N requirement of oilseed rape. In each year trials were carried out at ADAS Boxworth (Cambridgeshire) on a clay, ADAS High Mowthorpe (Yorkshire) on a shallow silty clay loam over chalk and at ADAS Rosemaund (Herefordshire) on a deep silty clay loam. Each N response experiment included two open pollinated oilseed rape cultivars (cv Castille and Winner), seven N rates ranging from zero to 360 kg N/ha (all applied as ammonium nitrate (34.5% N)), and two sets of application timings (Conventional and Canopy Managed). Conventional N timings involved applying 50% of the N in late February/early March just prior to stem extension and 50% at green bud (GS3,5-3,6). Canopy Management N timings involved applying 40 or 60 kg N/ha in late February/early March when the total fertiliser N requirement was greater than 200 kg N/ha. This early split was used on 3 of the 9 experimental crops. The remaining amount of N that was predicted to build an optimum sized canopy by flowering was applied at GS3,5-3,6. The amount of N required to achieve yields greater than 3.5 t/ha was applied between yellow bud (GS3,9) and early flowering (GS4,3). The cultivar and N timing treatments were arranged as a two-way factorial design with each treatment combination replicated four times and individual plots measuring 18m x 3.5m.

Analysis of variance procedures within Genstat 12 (www.genstat.com) were used to calculate whether treatments were significantly different. Linear plus exponential N response curves were fitted to the seed yield data for each treatment of the form

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

where *Y* is the seed yield (t/ha), *A, B, C* and *R* are constants. The economic N rate was determined from the fitted linear plus exponential parameters as follows;

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

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

Results

Several of the Canopy Management principles were tested in the experiments. It was shown that the combined amount of soil mineral N to a depth of 90 cm (or 60cm on shallow soils) and the amount of N taken up by the crop (both measured just prior to stem extension in February) correlated with the total amount of N that the unfertilised crops had taken up by harvest (Figure 1). On average the unfertilised crops took up 107% of the N measured in the soil and crop in February. It was likely that mineralisation during spring caused the N uptake efficiency to be greater than 100%. The equivalent efficiency with which fertiliser N was taken up by the crop was calculated by subtracting the N taken up by the crop without fertiliser from the N taken up with fertiliser and dividing by the rate of fertiliser N applied. This was carried out for 24 treatments across the three sites and three seasons. At the N rate that was closest to the economic optimum (which was 167 kg N/ha on average) the fertiliser N uptake efficiency was calculated at 57%.

At mid-flowering (GS4,5), the GAI correlated closely with the N content of the crop with each unit of GAI associated with 43 kg N/ha on average (Figure 2). The slope of this regression line was not significantly different from a slope of 50 kg N per unit of GAI. There was no significant difference in the amount of N contained within each unit of GAI between N rate, cultivar, site or year.

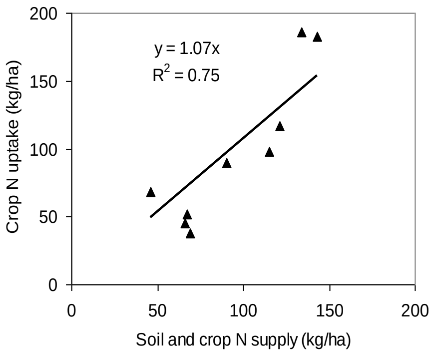


Figure 1. Relationship between the combined soil mineral N and crop N measured in February and the crop N uptake at harvest for crops grown at Boxworth, High Mowthorpe and Rosemaund in 2006, 2007 and 2008. Mean values across cvs Castille and Winner.

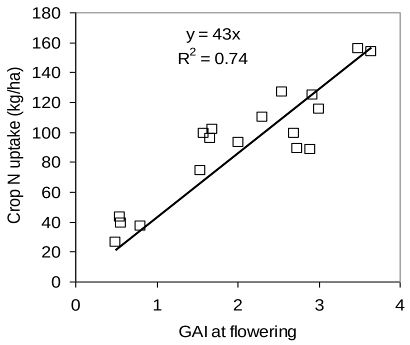
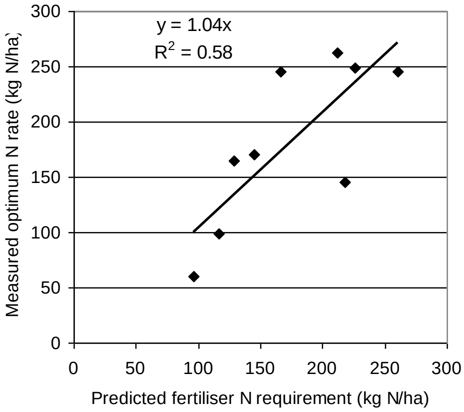


Figure 2. Relationship between GAI and crop N content at flowering for crops grown at 0 and 120 kg N/ha at Boxworth, High Mowthorpe and Rosemaund in 2006, 2007 and 2008. Mean values across cvs Castille and Winner.

The economic optimum N rates did not differ between cultivar or N timing strategy, and ranged between 60 and 263 kg N/ha between the nine experiments. The average yield at the optimum N rate in each experiment ranged from 3.31 t/ha to 4.98 t/ha. Across sites the yield at the optimum N rate was positively correlated with the total supply of N available to the crop (estimated as 100% of crop and soil mineral N measured in February plus 60% of the fertiliser N). On average, each additional tonne of yield was associated with an additional 36 kg/ha of plant available N, which would correspond to an additional 60 kg N/ha of applied fertiliser N (assuming 60% uptake efficiency). The Canopy Management N timing strategy increased yield of both cultivars by 0.22 t/ha at Boxworth in 2006 ($P<0.05$) where crop canopies were large following winter, and reduced yield by 0.14 t/ha at High Mowthorpe in 2007 ($P<0.05$) where dry conditions during spring reduced uptake of the later applied N applications. Yield was not affected by Canopy Managed N timings in the other experiments.

The Canopy Management principles were used to predict the fertiliser N requirement at each experimental site using information about the amount of soil mineral N and crop N measured just prior to stem extension in February and assuming a seed yield of 4 t/ha at each site. A linear regression between the predicted fertiliser N requirement and the measured optimum N rate accounted for 58% of the variation and the best fit line had a slope of 1.04 when forced through the origin (Figure 3a). If the measured yields were used to help predict the fertiliser N rate then the percentage of variation accounted for increased to 71% (Figure 3b). It is apparent from Figure 3b that N fertiliser requirement was over-estimated at one site. This may have been caused by additional N becoming available for crop uptake from mineralisation in the spring which was not accounted for.



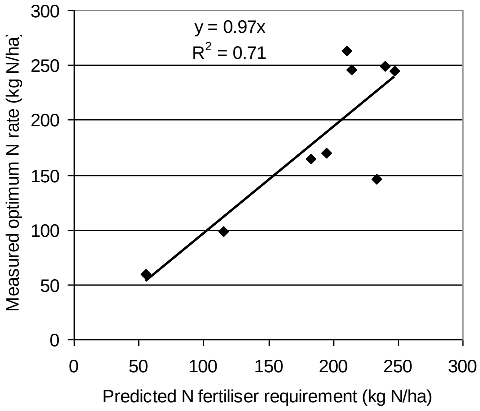


Figure 3. Relationship between the N fertiliser requirement predicted using Canopy Management principles by either assuming a) the same yield of 4 t/ha in each experiment or b) the measured yield at the optimum N rate. Each data point represents the mean value across cultivar and N timing treatments for an individual experimental site.

Discussion

Canopy Management principles have been shown to provide a good prediction of N fertiliser requirement. The prediction could be improved if a more accurate estimate of the yield potential of the field could be included in the calculation. Estimating the amount of additional N that will become available to the crop through mineralisation during the spring will also improve the prediction of N fertiliser requirement. It was shown that yields could be increased by delaying the first N application until green bud (GS3,5) when the GAI following winter was large (above 1.5) and there was sufficient soil moisture to allow later applied N to be taken up. This yield increase was caused by a reduction in lodging. Recent work has also shown that the Canopy Management principles apply for standard height and semi-dwarf hybrid cultivars.

References

Anon. (2010) *Fertiliser manual (RB209) 8th Edition*. pp. 252. Defra, London.

Holmes, R.J. and Ainsley, A. (1979). Nitrogen top-dressing requirements of winter oilseed rape. *Journal of the Science of Food and Agriculture* **30**, 119-128.

Lunn, G.D., Spink, J., Stokes, D.T., Wade, A., Clare, R.W. and Scott, R.K. (2001). *Canopy Management in winter oilseed rape.* Home-Grown Cereals Authority Project Report **OS49**. London.

Stokes, D. T., Scott, R. K., Sylvester-Bradley, R., Clare, R., Hopkinson, J., Milford, G. F. J. & Salmon, S. E. (1997). *An integrated approach to nitrogen nutrition for wheat*. Home-Grown Cereals Authority Project Report **159**. London.

Vaidyanathan, L.V., Sylvester-Bradley, R. & Bloom, T.M. (1987). Effects of previous cropping and applied nitrogen on grain nitrogen content in winter wheat. *Aspects of Applied Biology* **15**, Cereal Quality, 227-239.

Acknowledgements

Funding from GrowHow UK Ltd and the Home-Grown Cereals Authority is gratefully acknowledged.