EVALUATION OF A PRELIMINARY ALGORITHM FOR INCREASING FERTILIZER NITROGEN-USE EFFICIENCY IN CANOLA

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ABSTRACT

A field experiment with canola (*Brassica napus L.*) was conducted at Indian Head and Scott, Saskatchewan to evaluate the effects of various nitrogen (N) management strategies on grain yield and profitability. The treatment of greatest interest was a variable rate application where we applied a reduced rate of N at seeding and determined N topdressing rates using a preliminary N application algorithm. The algorithm was used to estimate fertilizer N requirements using sensor-based estimates of yield potential and potential responsiveness to additional N. The economic and agronomic feasibility of the variable rate treatment was evaluated against the traditional practice (referred to as the 'farmer practice' treatment), whereby the entire quantity of N required for a predetermined yield goal is applied at seeding. The normalized difference vegetation index (NDVI) of the crop was determined at the early bolting stage using a handheld, active optical sensor. At Indian Head, only minor differences in NDVI were observed between fertilized treatments, indicating that a response to further additions of N was unlikely. Consequently, we applied at total of 47 kg N ha^{-1} on the variable rate treatment compared with 100 kg N ha^{-1} on the farmer practice treatment. As expected, the yields of the two treatments were not significantly different from one another. At Scott, the absolute NDVI values were higher than those measured at Indian Head, but the trends were similar. The NDVI of the check was significantly lower than the other treatments. The differences between the remaining treatments were small. At Scott, the mean N fertilizer rate for the variable rate treatment was 70 kg N ha^{-1} compared with 116 kg N ha^{-1} for the farmer practice treatment. Unlike Indian Head, the variable rate treatment at Scott yielded less than the farmer practice treatment. Profitability of the variable rate treatment ranged widely from both plot to plot and between sites. At Indian Head, the variable rate treatment was more profitable than the farmer practice treatment as long as the price of canola was not too high and the price of N too low. At the lowest canola price and highest N price, the mean difference was nearly \$20 ha^{-1}. At Scott, where the variable rate plots had reduced yields, the farmer practice treatment was always more profitable. While the results to date are inconclusive, the study is scheduled to run for two more years.

INTRODUCTION

Canola responds well to fertilizer N, and recent studies suggest that optimum rates should be higher than those currently recommended (Brandt et al, 2004). High yielding canola hybrids use N more efficiently but also continue to respond to N rates that are above the maximum for lower yielding, open pollinated cultivars (Karamanos et al., 2005). As N rates used for this crop increase, it becomes more important that N management strategies make efficient use of this nutrient from both an environmental and economic standpoint. Such strategies aim to increase yield per unit N, or reduce the amount of N applied to achieve optimum yield. Accounting for spatial variations in the soil N supply and for year to year variations in the rate of mineralization of organic N could improve N fertilizer management considerably.

The optimum fertilizer N rate in canola production depends on the crop's yield potential, soil residual N, and mineralization of organic N. Depending how much N is mineralized from organic matter during the growing season, fertilizer rates based on pre-plant soil N levels can be unreliable (Ma et al., 2005). Mineralization rates are highly variable and difficult to predict as they are affected by many environmental factors (Cabrera et al., 2005). As a result, fertilizer N recovery in canola is typically less than 50%, and decreases with increasing N rates (Chamorro et al., 2002). Canola plants increase biomass production with increasing N availability, including recently mineralized N, until the nutrient is no longer limiting (Hocking et al., 1997). Consequently, when combined with non-N limited reference plots, crop-based indicators such as canopy reflectance, can be useful tools for estimating N status of crops (Johnson and Raun, 2003, Ma et al., 2005).

Vegetation indices such as normalized difference vegetation index (NDVI) are essentially measures of biomass production and as such, are useful tools for delineating management zones for precision agriculture (Basnyat et al., 2005). However, because plants accumulate biomass as the growing season progresses, NDVI alone is not a good estimator of yield potential in canola (Behrens et al., 2004). Lukina et al. (2001) successfully estimated the yield potential of winter wheat by dividing NDVI measured at a specific growth stage by the number of days between seeding and sensing where growing degree-days (GDD) exceeded zero. The authors proceeded to estimate N requirements by comparing the crop being fertilized with that of an adjacent crop grown in an N-rich environment. To our knowledge, nobody has yet used this approach to determine fertilizer N rates for canola.

The objective of this study was to compare the effects of various N management strategies on N fertilizer efficiency and profitability in canola production. The effects of using sensor-based estimates of N requirements to determine fertilizer N rates on canola yield and profitability were of particular interest.

MATERIALS AND METHODS

The studies were located at Indian Head (clay) and Scott (loam), on sites with a history of no-till management exceeding ten years. Soil samples collected early in the spring were analyzed for available N, phosphorus (P), potassium (K), and sulphur (S). The plots were direct seeded into standing cereal stubble. The same herbicide resistant, hybrid canola variety was used at both sites and weeds were controlled using registered herbicides. For P, K, and S, the specific fertilizer application methods and rates varied between sites, but were the same for all treatments within each site. We chose N free P, K, and S fertilizer forms to avoid applying N to the check treatments. Nitrogen rates at seeding were determined by subtracting residual NO_3-N from targeted total N levels. In the 0-60 cm soil profile, soil test results showed 33 and 48 kg NO_3-N ha^{-1} at Scott and Indian Head, respectively. Fertilizer N applied at seeding was mid-row banded urea and post-emergent N was surface dribble banded urea-ammonium nitrate (UAN), applied at early bolting of canola. The plots were swathed and subsequently, harvested using Wintersteiger plot combines. We evaluated six separate N management strategies (Table 1).

Except for the variable rate treatment, all N fertilizer rates were fixed. For the variable rate treatments, we estimated N requirements in a manner similar to that described by Lukina et al. (2001). We calculated the crop's growth rate by dividing NDVI by the number of GDD accumulated between seeding and sensing and used the resultant value in an exponential equation derived from limited data collected in 2004 to estimate yield potential. Nitrogen rates were calculated using the equation, $N_{REQ} = ((YP_N - YP_0) * GN) / E$ where R_{REQ} is the recommended N rate, YP_0 is the yield potential of the plot being assessed, YP_N is the mean yield potential of the non-N limiting plots, *GN* is the percent N in the grain, and *E* is an efficiency factor. With this algorithm, we assume that the sole reason for differences in estimated yield potential of YP_0 YP_N is N availability.

Table 1. Names and descriptions of the N management strategies evaluated at Indian Head and Scott, SK.

#	Name	Description
1	Check	No fertilizer N applied
2	Non-N Limiting	N applied at seeding[1] + residual NO_3^--N = 250 kg ha^{-1}
3	Farmer Practice	N applied at seeding + residual NO_3^--N = 150 kg ha^{-1}
4	Split App. / Fixed Rate	N applied at seeding + residual NO_3^--N = 90 kg ha^{-1}, 60 kg ha^{-1} applied post-emergent[2]
5	Split App. / Variable Rate	N applied at seeding + residual NO_3^--N = 90 kg ha^{-1}, post-emergent N rate determined using N fertilization algorithm
6	Reduced N[3]	N applied at seeding + residual NO_3^--N = 90 kg ha^{-1}

[1]urea applied as a mid-row band
[2]post-emergent N was surface dribble banded urea ammonium-nitrate
[3]The reduced N treatment was located at Indian Head only

A factorial combination of three canola prices (\$198, \$265 and \$330 tonne^{-1}) and three N prices (\$0.77, \$0.99 and \$1.21 kg N^{-1}) were chosen to estimate marginal profits. Marginal profits were calculated for each plot individually, and a \$12.50 ha^{-1} application cost was included when applicable. Profit for the variable rate treatments is expressed as dollars ha^{-1} relative to the mean profit calculated for the farmer practice treatment.

The experiment was set up as a randomized complete block design with four replicates and different N management strategies as the treatments. Due to changes in the protocol partway through the season, certain treatments had eight plots instead of four at both sites. Each site was analyzed as a separate experiment. We analyzed the data using the Proc GLM procedure in SAS 9.1, evaluating the effects of the N management strategies on plant density, NDVI, grain yield, and marginal profitability. Treatments means were compared using the protected LSD method and contrasts were used to compare the variable rate treatment directly with the farmer practice treatment. Results were declared significant at the 5% probability level.

RESULTS AND DISCUSSION

Temperature and moisture conditions in 2005 favoured high canola yields at both sites. At Indian Head and Scott, 321 and 335 mm of precipitation, respectively, fell between April 1 and August 31. Hail damaged the plots at Scott early in July, after the post-emergent N had been applied and damage reports for crops in the area ranged from 65 to 80%. While this may have introduced unknown biases to the canola yields measured at Scott, the damage appeared to be uniform across the treatments, and the standard errors were not unusual (Table 2). We decided to harvest the plots and use the data.

Table 2. Effects of various N management strategies on selected variables at Indian Head and Scott, SK.

	Location							
	Indian Head				Scott			
	kg N ha^{-1}	plants m^{-2}	---------	kg ha^{-1}	kg N ha^{-1}	plants m^{-2}	---------	kg ha^{-1}
Treatment	**Total N**†	**Plant Density**	**NDVI**‡	**Yield**	**Total N**†	**Plant Density**	**NDVI**‡	**Yield**
Check	0	72^{a}	0.271^{a}	2087^{a}	0	91^{a}	0.653^{a}	1713^{a}
Non-N limiting	200	72^{a}	0.405^{b}	3052^{c}	216	104^{a}	0.784^{bc}	2550^{c}
Farmer Practice	100	79^{a*}	0.391^{b*}	2942^{bc*}	116	98^{a*}	0.791^{c*}	2329^{c*}
Split / Fixed	100	73^{a}	0.351^{b}	2719^{b}	116	102^{a}	0.770^{bc}	2270^{bc}
Variable Rate	47	83^{a}	0.381^{b}	2776^{b}	70*	90^{a*}	0.753^{c*}	1953^{ab*}
Reduced N	41	77^{a}	0.356^{b}	2730^{b}	-------	-------	-------	-------
Standard Error	n/a	8.29 5.86*	0.020 0.014*	89.77 63.47*	n/a	12.30 8.70*	0.017 0.012*	148.82 105.23*

†Total quantity of fertilizer N applied, including both urea at seeding and post-emergent UAN.
‡NDVI measured just prior to UAN top-dressing applications

Values followed by the same letter are not significantly different from one another (LSD P≤0.05)

Plant emergence was excellent at both sites. Over 70% of the seeds placed at Indian Head became established plants. At Scott, plant establishment exceeded 90%. The treatments had no effect on plant establishment, likely a result of the large separation between the urea and the seed achieved with the mid-row banding application.

The rate of N applied at seeding affected NDVI values measured at the early bolting stage. At Indian Head, the check treatment had the lowest mean NDVI, providing evidence that the crop had responded to fertilizer N. The non-N limiting treatment had the highest mean NDVI, but was not significantly higher than any treatments except for the check. This implied that crop responses to N rates beyond 41 kg N ha^{-1} were minimal. While the absolute NDVI values measured at Scott were consistently higher than those at Indian Head, the trends were similar. Again, the check had the lowest NDVI of all the treatments. At this site, the farmer practice treatment had the highest mean NDVI, but the other treatments followed closely. Aside from the check, the only significant difference in NDVI between treatments occurred between the variable rate and the farmer practice treatments.

Because differences in NDVI were relatively small between treatments, the amount of post-emergent N applied to the variable plots was negligible. For example, at Indian Head top-dressing rates ranged from 0-11 kg N ha^{-1} for individual plots and averaged 6 kg N ha^{-1}. Rates were slightly higher at Scott, ranging from 0-48 kg ha^{-1} with a mean of 14 kg N ha^{-1}. At both sites, the variable rate treatments received considerably less N than the others, excluding the checks and the reduced N treatment at Indian Head.

Overall, yields at Indian Head were greater than at Scott, but this may reflect the hail damage incurred at Scott. We observed treatment effects on grain yield at both sites, but our results were inconsistent. At both sites, there was an overall yield response to N, with the checks yielding the lowest in both cases. Similarly, the non-N limiting treatments yielded the highest, 2550 and 3052 kg ha^{-1} at Scott and Indian Head, respectively. At Indian Head, the non-N limiting plots yielded significantly higher than all treatments except for the farmer practice. Grain yields of the reduced N, variable rate, split / fixed, and farmer practice treatments were not significantly different from one another. The variable rate treatment at Scott, on the other hand, yielded significantly lower than the farmer practice and non-N limiting treatments, and was not different from the check or the split application / fixed rate treatments.

Regardless of the treatment, profitability ranged widely from one plot to the next. Therefore, differences between the variable rate and farmer practice treatments were, in many cases, not statistically significant (Table 3). At Indian Head, the variable rate applications were more profitable, on average, than the farmer practice treatments as long as canola prices were relatively low and N prices were high. In all cases, profitability decreased as canola prices increased and N prices decreased. At Scott, because the variable rate treatment produced significantly lower yields than the farmer practice treatment, the profit analysis always favoured the farmer practice treatment. At high canola prices and low N prices, the difference exceeded \$100 ha^{-1}.

Table 3. Mean profitability of the variable rate treatment relative to the farmer practice treatment at various canola and N prices. Profit is expressed in dollars ha^{-1}.

N Prices ($ kg N^{-1})	SITE	Canola Commodity Prices ($ tonne^{-1}) Low 198	Medium 265	High 330
Low 0.77	Indian Head	-4.28 (0.86)†	-15.29 (0.60)	-26.29 (0.47)
	Scott	-51* (0.09)	-76* (0.06)	-101** (0.05)
Medium 0.99	Indian Head	7.50 (0.73)	-3.51 (0.91)	-14.51 (0.69)
	Scott	-41 (0.17)	-66* (0.10)	-91* (0.08)
High 1.21	Indian Head	19.28 (0.38)	8.27 (0.79)	-2.73 (0.94)
	Scott	-31 (0.30)	-56 (0.16)	-81 (0.11)

†Values in brackets are p-values obtained from contrast statements comparing the farmer practice and variable rate treatments

*significant at P≤0.1
**significant at P≤0.05

CONCLUSIONS

The results from the first year of the study are somewhat inconclusive. The variable rate treatments at Indian Head showed promise, with grain yields being maintained using considerably less fertilizer N. At Scott, however, the results favoured the farmer practice treatments. We are not yet able to calculate precise fertilizer N-use efficiencies, but can assume that, at Indian Head at least, the variable rate treatment increased fertilizer N-use efficiency. The study is being funded for two more years at both locations, and a similar experiment is being conducted on a field scale. By the end of this three-year project, we hope to have enough data to draw meaningful conclusions regarding the economic and agronomic feasibility of using sensor-based estimates of fertilizer requirements for canola.

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