

Long-term residual effects of alternative nitrogen management practices in canola production systems (Project A08711)

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Submitted to the Saskatchewan Canola Development Commission, December 2016

Introduction:

Nitrogen (N) fertilizer is one of the key inputs in most annual crop production systems. While research has typically focussed on the effect of N management in the year of implementation (Grant et al. 2010; Grant et al. 2011; Mahli et al. 2007), N fertilization strategies and decisions may also have longer-term implications for N dynamics in cropping systems (Campbell et al. 1994; Grant et al. 2016).

Significant research has been conducted in an effort to improve N use efficiency in cropping systems. Management practices that better match N supply with crop N demand have the potential to improve N use efficiency by the crop, and to reduce the potential for over-application of N that can lead to N accumulation in the soil and/or losses into the environment. Improving the efficiency with which fertilizer N is used by the crop can also enhance economic returns for growers. Managing N in agricultural systems remains challenging, however, because the N cycle is complex and may be affected by many factors including not only management practices, but also environmental conditions.

Various technologies have aimed to improve our ability to accurately meet crop N demands. Soil testing, often combined with knowledge of the soil characteristics and cropping history of a given site, have traditionally been used to refine N fertilizer rates (Manitoba Agriculture Food and Rural Initiatives 2013). More recently, split application of N and the use of optical sensors in-crop have been assessed in western Canada as a means to better match N supply to crop N demand (Grant et al. 2012; Holzapfel et al. 2009; Lafond et al. 2008; Malhi et al. 2010).

Despite these efforts, lower or higher than optimum N fertilizer rates may sometimes be applied, in part, due to the limitations of these technologies. While the soil nitrate test is generally an effective and valuable tool, its efficacy may be influenced by sampling technique and by conditions in a given field. Proper sampling technique is critical to ensuring accurate fertilizer recommendations (Manitoba Agriculture Food and Rural Initiatives 2013). However, even with proper sampling technique, limitations may exist. For example, fields with low soil nitrate concentrations may not respond to fertilizer N in those cases where significant mineralization of soil N occurs during the growing season (Flaten 2001).

The efficacy of in-crop N application may also vary, being beneficial in some but not all cases. In studies conducted across the Northern Great Plains and the Pacific Maritimes, split application of urea (50% at seeding; 50% in-crop) increased yield in limited situations, primarily under high moisture conditions, but consistent improvements in crop yield, crop N status and N use efficiency were not observed compared to standard fertilization practices in those regions (Grant et al. 2012). In studies in Saskatchewan, Holzapfel et al. (2009) similarly found no yield benefit to split application of N compared to application of N at seeding. However, using optical sensing technology to determine in-crop N application rates reduced N inputs by 15 to 53% with no effect on seed yield in 5 of 6 site-years. In one site-year, dry conditions contributed to a yield decline when optical sensing technology was used rather than spring N application. While the use of sensors slightly increased agronomic N use efficiency in some cases, no reduction in post-harvest soil nitrate-N levels was observed in this study.

Environmental and other factors may also influence N dynamics in a cropping system, and may contribute to under- or over-application of N fertilizer in a given year. Growing season conditions may lead to unusually poor or good growth in a given year, resulting in significantly

lower or higher crop N uptake and removal than expected based on averages for the region. Wet conditions in-season may contribute to unexpected N losses from the soil, or preclude planned N fertilizer applications. Overlaps in equipment passes may also contribute to higher than planned fertilizer N rates in select areas of a field.

While N management practices, and occasional under- or over-application of fertilizer N are expected to influence N availability and crop yield in the year of application, information regarding the impacts on N availability in subsequent years is limited. A better understanding of the cumulative effect of N management practices applied over time may help to identify the relative risks and benefits associated with specific management decisions, while information regarding N availability following a poor versus excellent crop may provide some insights into possible N management strategies to address these situations.

Objective:

As part of the Canola Cluster research program, a field study was conducted near Brandon, MB from 2010 through 2013, to determine the effect of N management on crop yield, and on N input and removal, in a 2-year canola/spring wheat rotation. The objective of the current study was to determine the effect of previous N management on plant-available N levels in two subsequent growing seasons (2014 and 2015). Also, because this study produced very high wheat yields but very poor canola yields (due to poor emergence) in 2013, the effects of a preceding crop failure versus a high-yielding crop on N availability in the following growing seasons (2014 and 2015) were also determined. While this study was conducted in Manitoba, results are expected to apply to similar ecozones in Saskatchewan.

Materials and Methods:

In both 2014 and 2015, wheat was established as an indicator crop across the site of a previous canola-wheat rotation to which various N management practices had been applied.

The previous rotation study conducted from 2010-2013 was a 2-year fully phased rotation of canola-spring wheat, arranged as a randomized complete block design with four replicates (2 crops x 12 N treatments x 4 reps = 96 plots) and conducted near Brandon, MB. Plot dimensions were 3.65 x 15 m. Treatments consisted of: a "farmer practice (FP)" N rate based on soil testing; four "0N checks" (which received 0 N in one of 2010, 2011, 2012 or 2013, and the FP rate in the remaining three years of the study); four "N-rich" treatments (which received 150% of the FP rate in one of 2010, 2011, 2012 and 2013, and the FP rate in the remaining 3 years of the study); a split-application treatment based on the FP rate alone (66% of the FP rate at seeding, balance in-crop); and two split-application treatments based on the optical sensor (66% of the FP rate at seeding with the balance applied if required based on optical sensor, or 100% of the FP rate at seeding plus additional N if required based on the optical sensor). In 2013, the experiment produced high wheat yields overall averaging 3730 kg ha⁻¹ (67 bu/ac), while the canola was a crop failure producing <5 bu/ac on average.

In each of 2014 and 2015, the entire experimental area was seeded to an indicator crop of spring wheat (*Triticum aestivum* cv 'Glenn') using a ConservaPak seeder with hoe openers. Seeding dates were June 4, 2014 and May 5, 2015. No N fertilizer was applied, except in the form of monoammonium phosphate. A rate of 50 kg P₂O₅ ha⁻¹ as monoammonium phosphate was applied to all plots to ensure P sufficiency, which provided approximately 10 kg N ha⁻¹. Generally-accepted agronomic practices for the region were employed. Recommended herbicides were applied at recommended rates to manage the weeds present. Fungicide was applied as required to control leaf diseases in order to minimize any potential differences in disease for wheat following wheat versus canola.

In each of 2014 and 2015, plant stand was determined 1-2 weeks after crop emergence by counting 2-1m lengths of row in each plot. Greenseeker measurements were collected weekly beginning at approximately the three-leaf stage and continuing for four to five weeks. Grain and straw yield were determined using a plot combine. In 2015, an error during combining resulted in the loss of data from several plots, which were considered missing values when data were analyzed. Percent protein in grain was determined by NIR using a Foss Infratec™ Grain Analyzer (Foss, Eden Prairie, MN), and test weight was determined using the test weight module on the same instrument. Seed weight was determined by counting and weighing 1000 seeds. Grain N concentration was estimated from percent protein using a conversion factor of 5.8. A subsample of straw was dried and ground, and total N concentration determined by combustion.

Soil samples were collected periodically over the course of the study. In fall 2013, soil samples were collected at a depth of 0-15 and 15-60 cm from select treatments (0, 100%, 150% of Farmer Practice N rate following canola and wheat). In the fall of 2014 and 2015, soil samples were collected at a depth of 0-15, 15-30 and 30-60 cm from each treatment, and bulk density determined based on the volume and dry weight of the soil cores collected. Soil samples were air-dried, ground, and soil NO₃ and NH₄ concentration determined on a 2 M KCl extract. Soil N content was calculated based on measured bulk density. In addition, in spring 2014, soil samples were collected at a depth of 0-15 cm, dried and ground. Mineralizable N was estimated by determining the ultraviolet absorbance of a 0.01 M NaHCO₃ extract at 205 nm, as described by Sharifi et al. (2007).

Data for this report were analyzed using PROC MIXED in SAS to determine the effect of preceding crop and preceding N management on crop productivity and N dynamics. Single degree of freedom contrasts were employed to compare specific treatments or groups of treatments. Tukey's multiple comparison procedure was also used to determine differences among treatments. Where a significant preceding crop x preceding N management interaction was observed, data were re-analyzed by preceding crop. A probability value of ≤0.05 was considered statistically significant for the purposes of this report.

Results and Discussion:

Fall 2013

Average soil nitrate levels measured in fall 2013 immediately after the canola-wheat rotation were generally higher after the poor canola crop than the high-yielding wheat crop, likely due to lower levels of N uptake and removal by the very low yielding canola crop. Soil nitrate content after canola was estimated to be 33, 64 and 48 kg ha⁻¹ to 60 cm for 0, 100% and 150% of the Farmer Practice N rate, compared to 29, 30 and 38 kg ha⁻¹ to 60 cm after wheat for 0, 100% and 150% of the Farmer Practice N rate.

2014

In 2014, preceding crop markedly and consistently affected crop yield and N status. In 2014, unfertilized wheat grown immediately following the poorly-yielding 2013 canola crop yielded approximately 115% that following a high-yielding wheat crop (Table 1). Seed weight was also higher for wheat following the poorly-yielding canola crop than the high-yielding wheat crop, while test weight was slightly lower (Table 1).

Consistently higher in-crop Greenseeker readings, together with a higher percent protein in harvested grain (14 vs 13.3%), indicated increased N availability following the poor canola crop (Table 1). This was reflected in the higher total N uptake in wheat grain + straw (77 vs 62 kg N ha⁻¹), and the higher amount of N removed in harvested grain (54 vs 45 kg N ha⁻¹) (Table 2). Following grain harvest in 2014, soil nitrate content to a depth of 60 cm remained slightly

higher where wheat had been established after the poorly-yielding canola versus the high-yielding wheat crop (27 vs 23 kg NO₃-N ha⁻¹ to 60 cm). Estimated available N supply in fall 2014 (calculated as the sum of total N uptake by the 2014 wheat crop at harvest plus soil nitrate-N content to 60 cm measured post-harvest) was higher following the poor canola crop compared to the high-yielding wheat crop (104 vs. 85 kg N ha⁻¹) (Table 3). Preceding crop had no effect on mineralizable N measured in spring 2014 (Table 3).

Analysis of variance demonstrated no effect of preceding N management or preceding crop x preceding N management interactions, on measurements taken in 2014 (Tables 1 and 2). The only exception was grain protein, which was slightly higher for the 2014 wheat crop where preceding N management had consisted of a 100% N rate versus a 66% N rate + additional N as determined by Greenseeker readings. Subsequent contrast analysis to assess effects of preceding N management on N status demonstrated higher N uptake in grain, N uptake in grain+straw, fall soil nitrate content, and available N supply where 1 in 4 of the preceding years (2010-2013) had included a 150% N rate versus a 0% N rate (Table 2).

2015

By 2015, the second year following the low-yielding canola and high-yielding wheat crops of 2013, differences between preceding crop treatments appeared to diminish. In 2015, plant stand in wheat was similar regardless of treatment (Table 3). While in-crop Greenseeker measurements were higher following the poor-yielding 2013 canola crop as compared to the high-yielding 2013 wheat crop for the first two sampling dates (June 16, June 24) suggesting greater N availability earlier in the growing season, preceding crop had no effect on Greenseeker readings taken on subsequent sampling dates. Despite this, percent protein in grain was higher following the 2013 canola crop than the 2013 wheat crop. Test weight was lower following the poorly-yielding 2013 canola crop than the high-yielding wheat crop, which had also been observed in 2014. Treatments did not affect seed weight, however. Neither fall soil nitrate content nor available N supply was affected by preceding crop treatment (Table 4).

Analysis of variance demonstrated limited effects of N management and/or preceding crop x N management interactions in 2015 (Tables 3 and 4). Although analysis of variance suggested a significant effect of preceding N treatment on the Greenseeker measurements taken on July 8th, neither contrast analysis nor multiple comparison procedures revealed differences among treatments. For the next sampling date of July 15th, Greenseeker readings were slightly higher for the treatment that had received 150% N in 2012, suggesting higher N availability, than for the treatments that received 0 N in either 2011 or 2012. Subsequent contrast analysis to assess the effect of preceding N management on N status of the production system demonstrated higher fall nitrate content and higher available N supply where 1 in 4 of the preceding years (2010-2013) had included a 150% N rate versus a 0% N rate (Table 4). In addition, the 100% N treatment resulted in higher grain N uptake than treatments receiving 0 N in 2013 or those receiving a 66% N rate + additional N as determined by optical sensors.

In 2015, significant preceding crop x N management interactions were evident for grain yield and total N uptake by the crop, suggesting that effects of preceding N management differed depending on whether the 2013 preceding crop was a poor-yielding canola crop or a high-yielding wheat crop. Separate analysis for each preceding crop showed that N management had no effect on grain yield or N uptake of the 2015 wheat crop when grown following the low-yielding canola crop in 2013 (Table 4). In contrast, grain yield and N uptake of the 2015 wheat crop was lower where 0 N rather than 100% or 150% N had been applied to a high-yielding wheat crop in 2013. In part, growing a high-yielding wheat crop with 0 N fertilizer applied in 2013 may have depleted N reserves resulting in lower yields in 2015, although similar trends did not appear to be evident for fall soil nitrate levels or available N supply measured in fall 2015.

Summary:

Wheat receiving no N fertilizer was established for two consecutive years (2014, 2015) across the site of a previous canola-wheat rotation to which various N management practices had been applied for the period 2010-2013. For each rotation conducted from 2010-2013, wheat had been grown in 2 of 4 years and canola had been grown in 2 of 4 years. In 2013, however, the wheat phase of the rotation yield well ($\approx 3700 \text{ kg ha}^{-1}$), while the canola phase of the rotation was a crop failure producing negligible yields (due to poor emergence).

Residual effects of preceding crop and preceding N management were evident both in 2014 and 2015. In 2014, higher grain yield and increased N availability were evident following the poorly-yielding 2013 canola crop compared to the high-yielding 2013 wheat crop, likely due at least in part to lower N demand and removal by the 2013 canola crop. On average, those treatments that included a 1 in 4 year application of 150% N rate resulted in increased crop N uptake, fall soil nitrate content, and available N supply compared to those treatments that included a 1 in 4 year application of 0 N. Effects of preceding treatments appeared to diminish somewhat by 2015; however, fall soil nitrate content and available N supply followed a similar trend as in 2014.

These findings demonstrate that preceding crop and N management have the potential to impact N availability in the cropping system in subsequent years. As such, previous management and production should be considered when making N management decisions. Observed differences in soil nitrate levels suggest that soil testing may provide information regarding residual N effects and therefore may be a helpful tool for growers when making fertilizer decisions. Grant et al. (2016) similarly reported that residual effects of N fertilizer can increase the plant-available N supply for up to two years after the final N fertilizer application under the cool, dry conditions common to the Canadian prairies. Despite the contributions of in-season N mineralization to the plant-available N supply, Grant et al. (2016) found that soil test nitrate provided an indication of residual N and recommended soil testing as a tool for producers when selecting N fertilizer rates.

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