Influence of Time and Method of Terminating Alfalfa Stands on Soil N Supply, Crop Yield, N Uptake, Soil Organic C and N, and Greenhouse Gas Emissions

S. S. Malhi[1], J. J. Schoenau[2], R. L. Lemke[3] and D. Leach[1]

[1]Agriculture and Agri-Food Canada, Research Farm, P.O. Box 1240, Melfort, Saskatchewan, Canada, S0E 1A0; Phone: 306-752-2776 Ext. 230; Fax 306-752-4911; E-mail: sukhdev.malhi@agr.gc.ca; [2]Department of Soil Science, University of Sask., Saskatoon, SK, Canada; and [3]Agriculture and Agri-Food Canada, Saskatoon Research Centre, Saskatoon, Saskatchewan, Canada

Background

- In the Parkland region, alfalfa (*Medicago sativa* Leyss.) is often grown (for forage or seed production) in rotation with annual crops, to reduce fertilizer N input, while also improving seed yield/protein content and soil quality (particularly in Gray Luvisol soils low in organic matter).
- After about 3 years, alfalfa cannot maintain its original productivity and is terminated, usually by tillage, which exposes soil to erosion, can lead to crusting, resulting in poor emergence of subsequent crops.
- This can also result in substantial release of nitrate-N from soil organic N (subject to leaching and denitrification), and CO_2 and N_2O gas emissions into the atmosphere.
- Herbicides that control alfalfa effectively have been identified. Therefore, termination without tillage could be a feasible alternative to tillage for stand termination.

Objective

To compare the influence of time and method of terminating alfalfa stands on seed yield, quality, N uptake and N fertilizer requirements for wheat (*Triticum aestivum* L.) and canola (*Brassica napus* L.), soil mineral N, aggregation and organic C and N, and nitrous oxide (N_2O) emissions.

Materials and Methods

- Termination treatments were initiated on 7-yr old alfalfa in summer 2003 near Star City, Saskatchewan on a Gray Luvisol (Boralf) loam soil (3.1% organic matter). Growing season precipitation (May-August) at Melfort Research Farm was 290 mm in 2004, 372 mm in 2005, 220 mm in 2006 and 304 mm in 2007 (long-term average 240 mm).
- The 36 treatments were 3 x 3 x 4 factorial combinations of 3 termination methods (herbicide (NT), tillage, and herbicide + tillage), 3 times of termination (after first cut,

after second cut and spring) and 4 rates of N (0, 40, 80 and 120 kg N ha^{-1}) with 4 replications (RCBD). Herbicides were Lontrel + 2,4-D and Glyphosate + 2,4-D.

- All plots received blanket applications of P, K and S fertilizers each spring. The plots were seeded to annual crops in a rotation of wheat (*Triticum aestivum* L. cv. CPS 500PR) in 2004, canola (*Brassica napus* L. cv. Invigor 2573 - hybrid) in 2005, wheat (cv. HRSW AC Barrie) in 2006 and canola (*Brassica napus* L. cv. Invigor 5108 - hybrid) in 2007.

Summary of Results

First Growing Season (2004) After Termination

– Wheat –

- Soil nitrate-N was higher with tillage or herbicide + tillage than herbicide in autumn 2003 and spring 2004, and decreased with delay in termination.
- Maximum seed yield and N uptake was produced from termination in spring in herbicide, and from termination after cut1 in tillage and herbicide + tillage treatments.
- Delay in termination with tillage or herbicide + tillage decreased seed yield and N uptake, but the negative influence was much larger at 0 and 40 kg N ha^{-1} than at 80 and 120 kg N ha^{-1} rates.
- Spring was the best time for termination using herbicide, but herbicide method produced lower yield and N uptake than tillage or herbicide + tillage, with termination after cut 1 and cut 2.
- Differences in seed yield and N uptake with different termination methods were relatively greater at lower than at higher N rates, and with earlier than later stand termination time.
- There was usually no significant increase in seed yield above 80 kg N ha^{-1} (except for herbicide in spring where it continued to increase up to 120 kg N ha^{-1} rate).
- Protein concentration (PC) increased with increasing N rate. It was highest with herbicide method and lowest with spring termination. The differences between termination times were highest for herbicide method.
- Mean cumulative N_2O loss during 2004 ranged from 220 to 420 g N ha^{-1}. There were negligible N_2O emissions during the snow melt period likely due to dry conditions in previous autumn and limited snow cover in winter. The N_2O loss tended to be lower with termination after cut 1 than the other termination times. N_2O emissions from tillage termination were significantly higher than termination by herbicide.

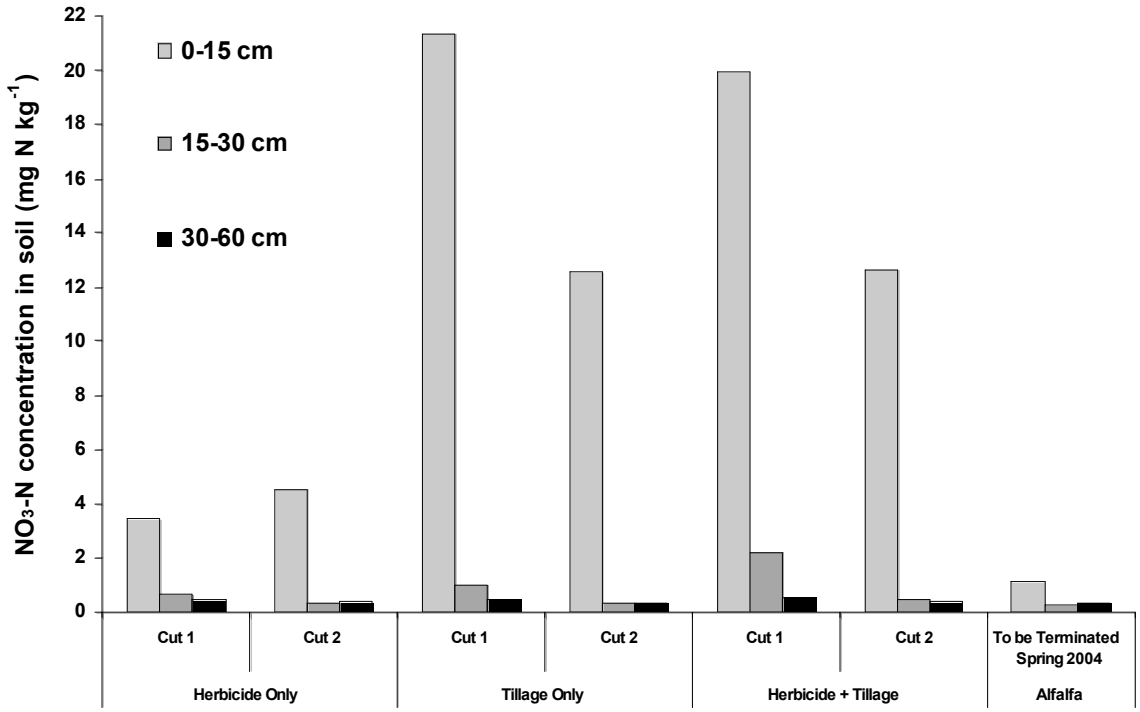

Figure 1. Nitrate-N concentration in soil in the zero-N treatment for 3 termination methods and 3 termination times in autumn 2003 (termination of alfalfa was done in summer of 2003 or in spring 2004) at Star City Saskatchewan.

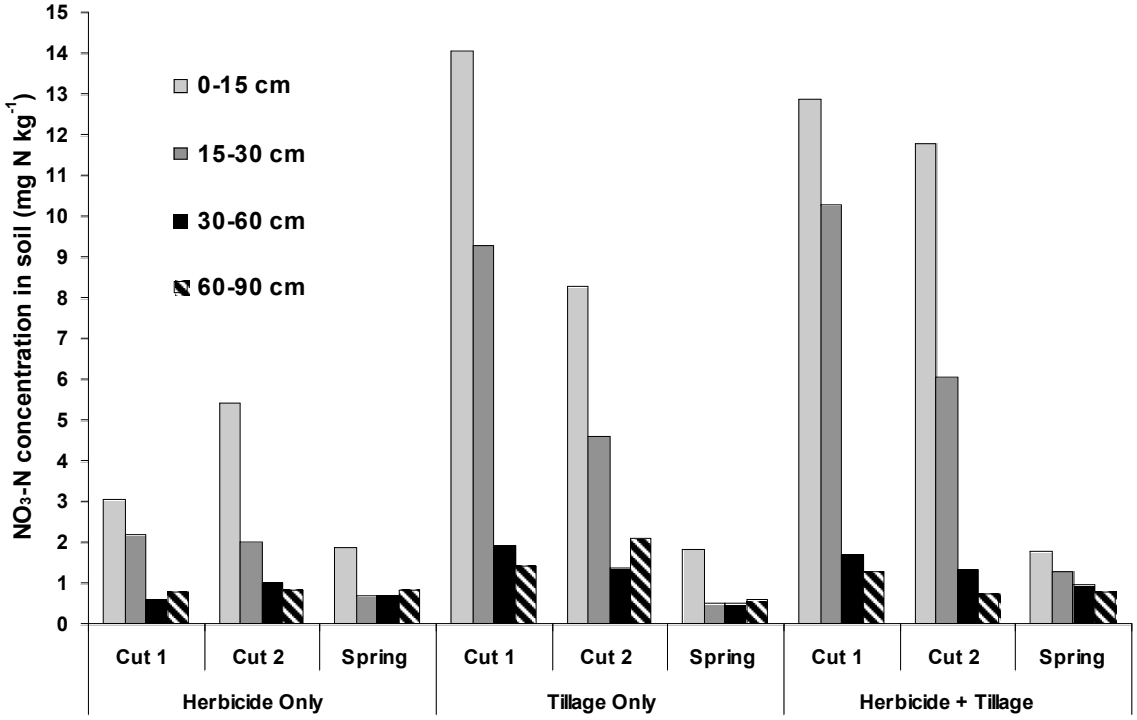

Figure 2. Nitrate-N concentration in soil in the zero-N treatment for 3 termination methods and 3 termination times in spring 2004.

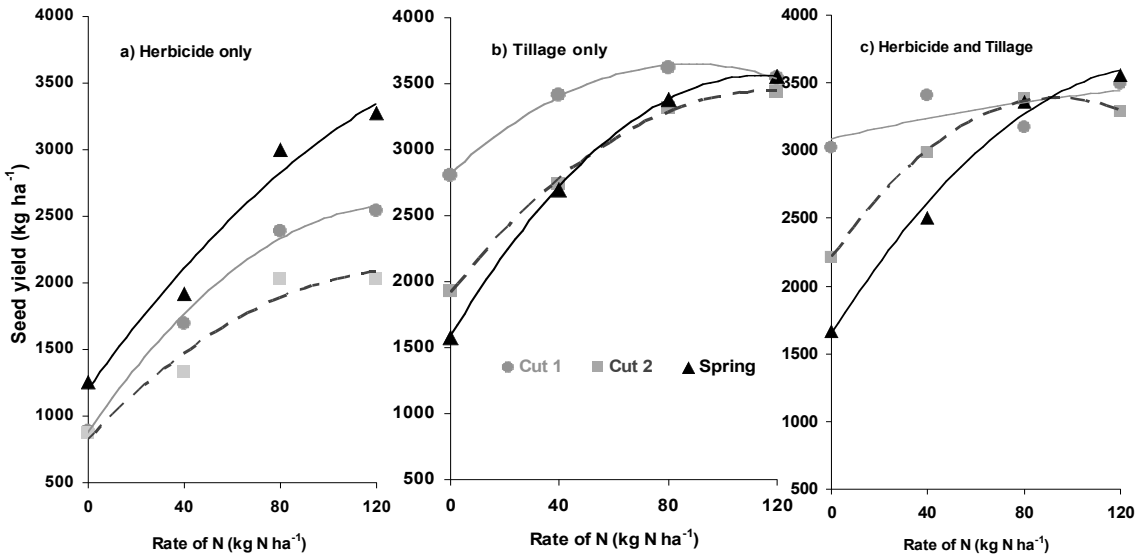

Figure 3. Seed yield of CPS wheat for termination method x termination time x rate of N in 2004.

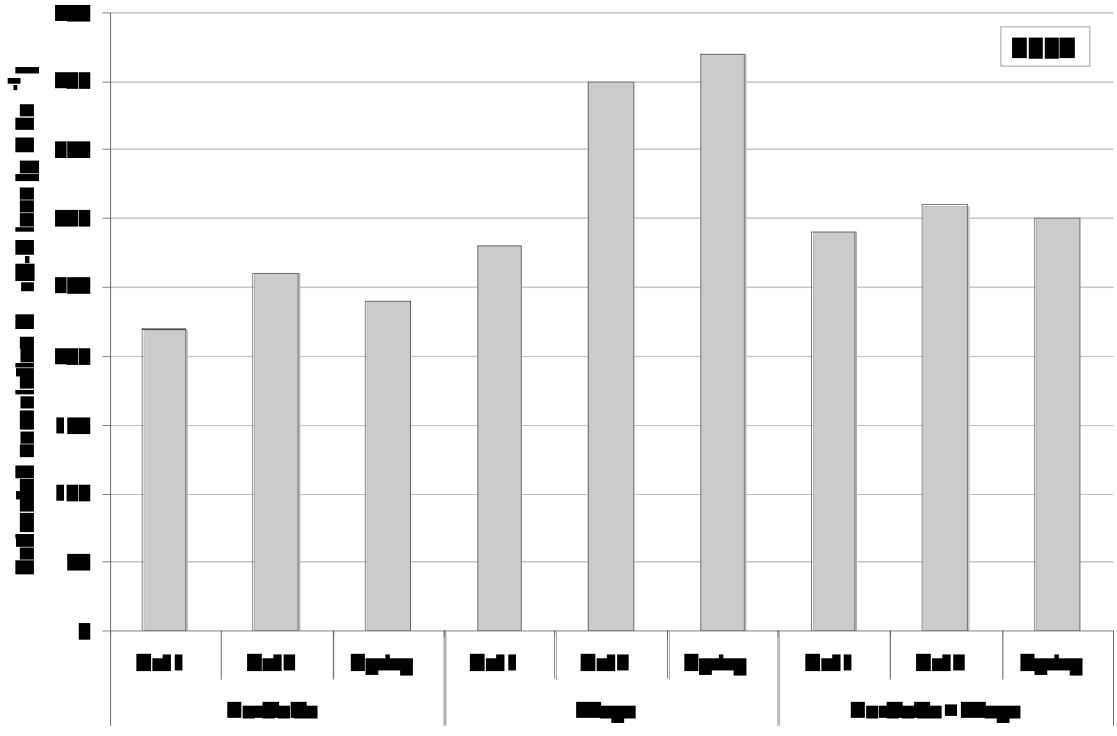

Figure 4. Estimated cumulative N_2O-N emissions in the zero-N treatment for 3 termination methods and 3 termination times in 2004.

Summary of results

Second Growing Season (2005) After Termination

– Canola –

- In spring 2005, soil nitrate-N was higher in herbicide than tillage or herbicide + tillage.
- Seed yield, protein concentration and N uptake increased, but oil concentration decreased with increasing rate of N application.
- There was no significant effect of termination time or method on seed yield, but in the zero-N treatment seed yield, PC and N uptake tended to be higher and oil concentration tended to be lower with herbicide than tillage or herbicide + tillage methods.
- In seed, oil concentration increased, but PC and N uptake decreased with delay in termination. Oil concentration was higher with tillage or herbicide + tillage methods, but opposite was true for PC and N uptake in seed.
- Mean cumulative N_2O loss during 2005 ranged from 330 and 730 g N ha^{-1}. N_2O emissions during the snow melt period were substantially higher (representing 16 to 55% of the cumulative seasonal totals). The N_2O loss tended to decline with delay in termination. In the second year, N_2O emissions from tillage termination were lower than termination by herbicide. This is consistent with tillage producing a greater flush of microbial activity and nitrate release in the first year that diminished by the second year.

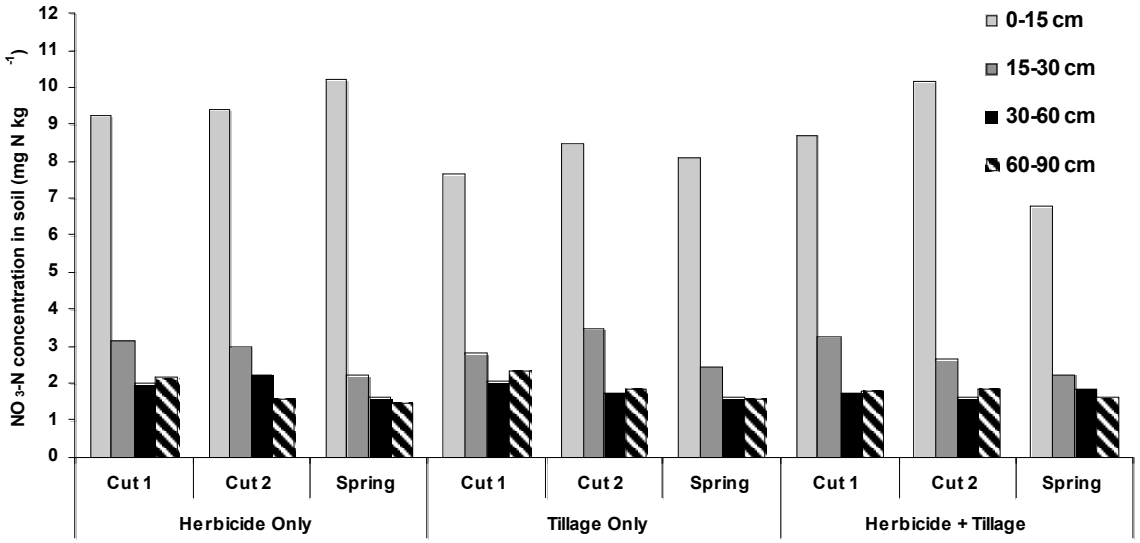

Figure 5. Nitrate-N concentration in soil in the zero-N treatment for 3 termination methods and 3 termination times in spring 2005.

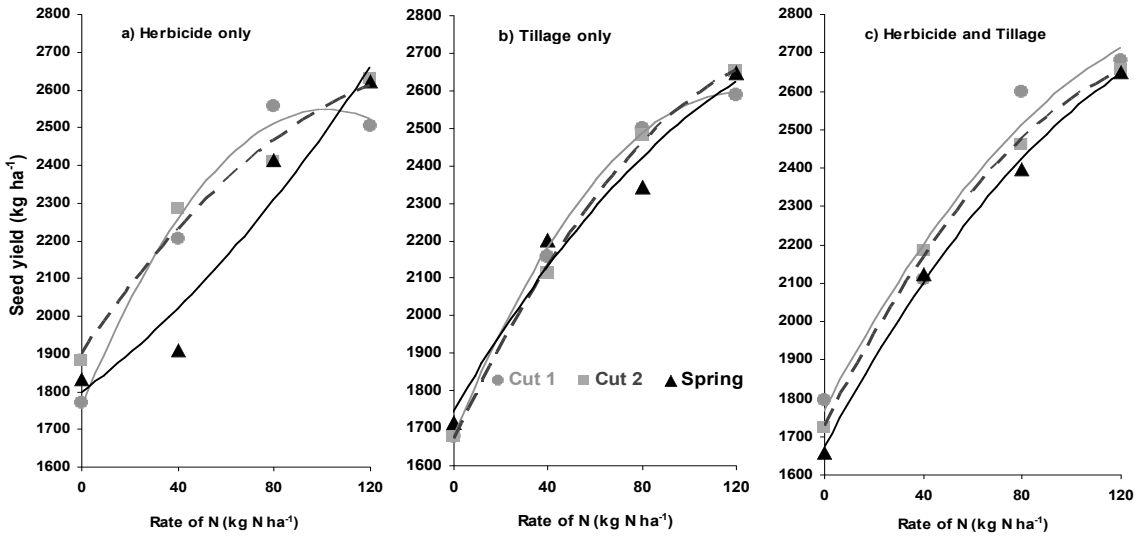

Figure 6. Seed yield of hybrid canola seed for termination method x termination time x rate of N in 2005.

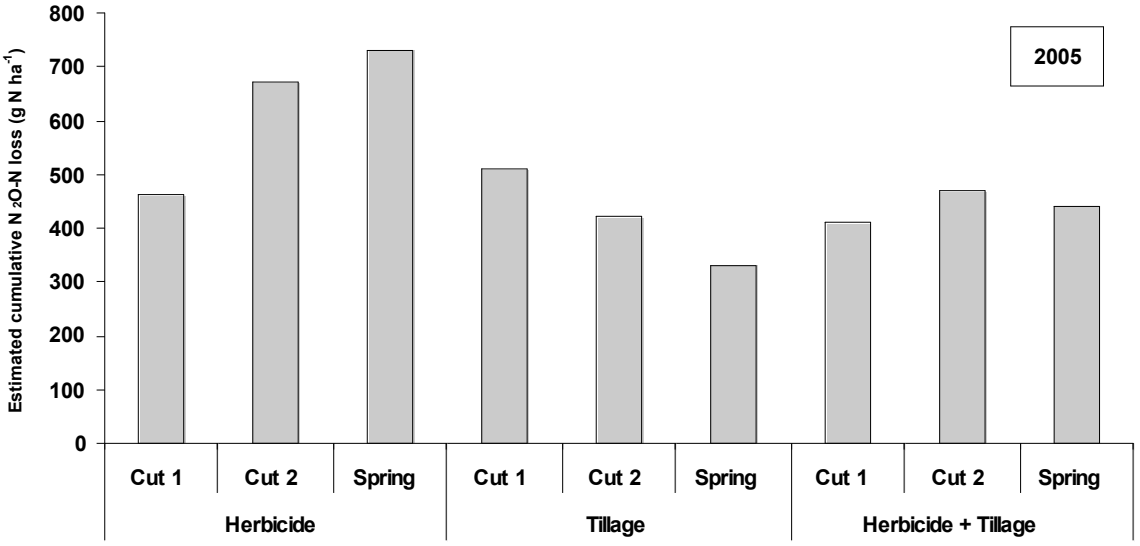

Figure 7. Estimated cumulative N_2O-N emissions in the zero-N treatment for 3 termination methods and 3 termination times in 2005.

Summary of results

Third Growing Season (2006) After Termination

– Wheat –

- There was a significant effect of termination method on soil nitrate-N in the 0-15 cm depth in spring 2006.
- Seed yield increased with increasing N rate. There was no significant effect of termination time or method on seed yield, but in the zero-N treatment seed yield tended to be lower with herbicide method than tillage or herbicide + tillage method.
- Mean cumulative loss of N_2O-N ranged from 150 to 330 g N ha^{-1} at the zero-N rate, and it was again higher from herbicide treatments than on tillage treatments in 2006.

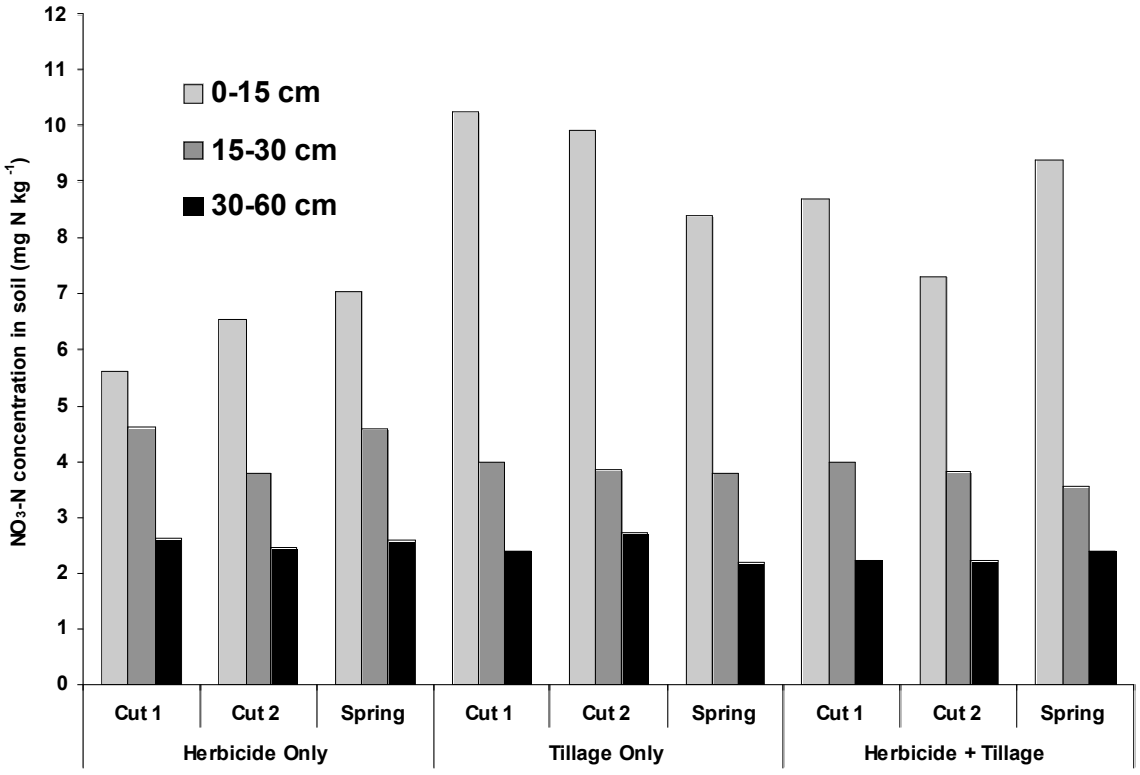

Figure 8. Nitrate-N concentration in soil in the zero-N treatment for 3 termination methods and 3 termination times in spring 2006.

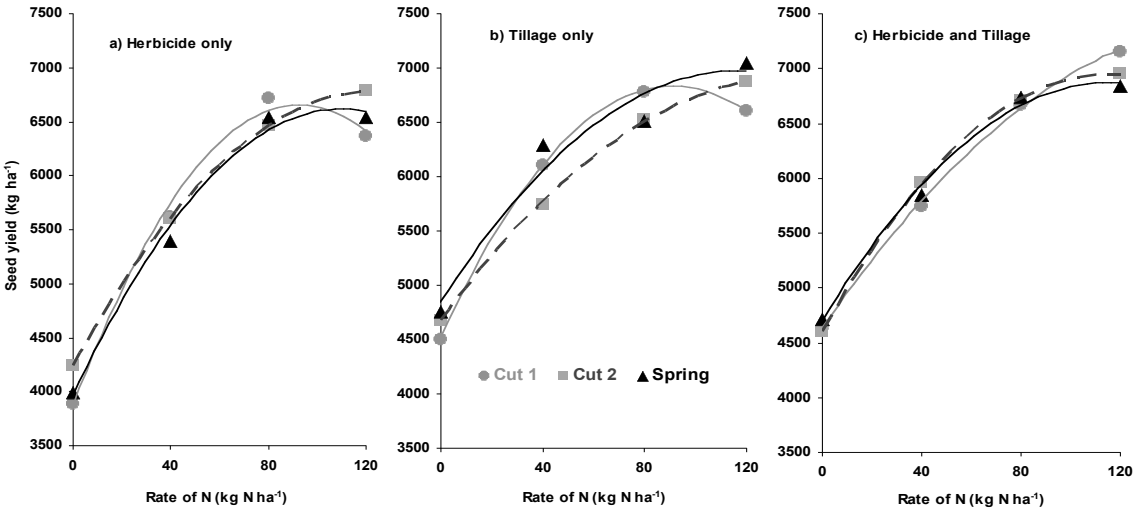

Figure 9. Seed yield of HRS wheat seed for termination method x termination time x rate of N in 2006.

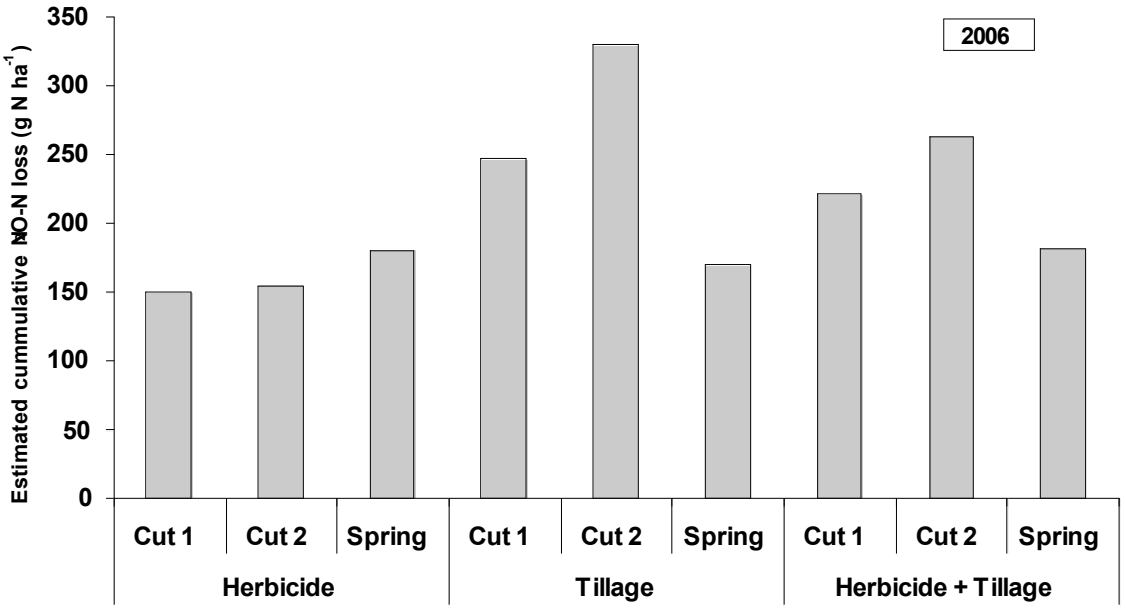

Figure 10. Estimated cumulative N_2O-N emissions in the zero-N treatment for 3 termination methods and 3 termination times in 2006.

Summary of results

Fourth Growing Season (2007) After Termination

– Canola –

- In spring 2007, there was no effect of termination method or time on soil nitrate-N, but it tended to increase with N rate
- Seed yield increased with increasing N rate, but there was no significant effect of termination time or method on seed yield.
- In 2007, mean cumulative loss of N_2O-N ranged from 220 to 425 g N ha^{-1} at the zero-N rate, and from 371 to 849 g N ha^{-1} at the 80 kg N ha^{-1} rate. There was no influence of termination method on N_2O emissions.
- The N_2O emissions during snow melt period of 2005

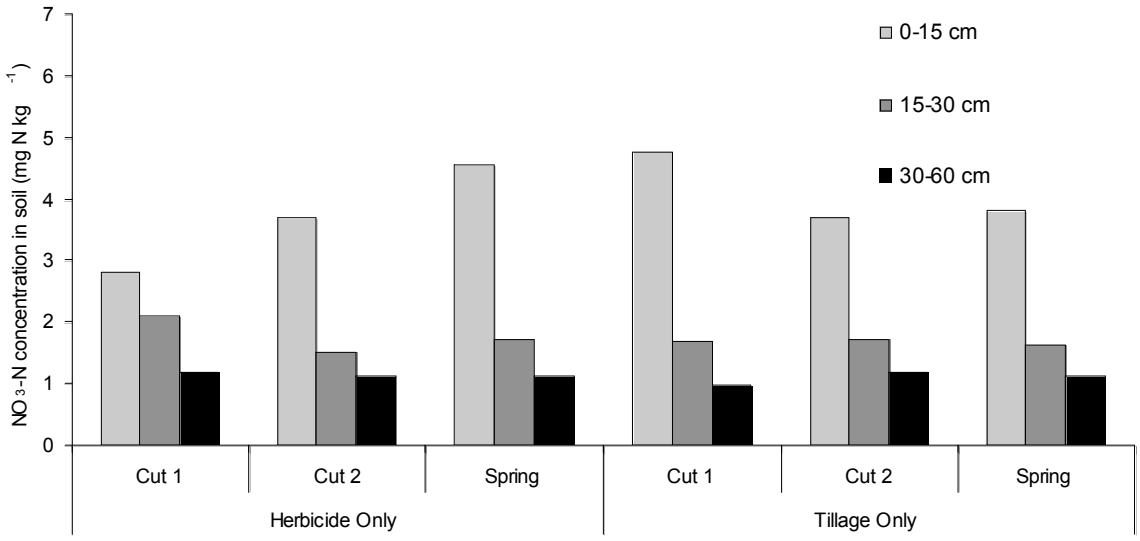

Figure 11. Nitrate-N concentration in soil in the zero-N treatment for 3 termination methods and 3 termination times in autumn 2007.

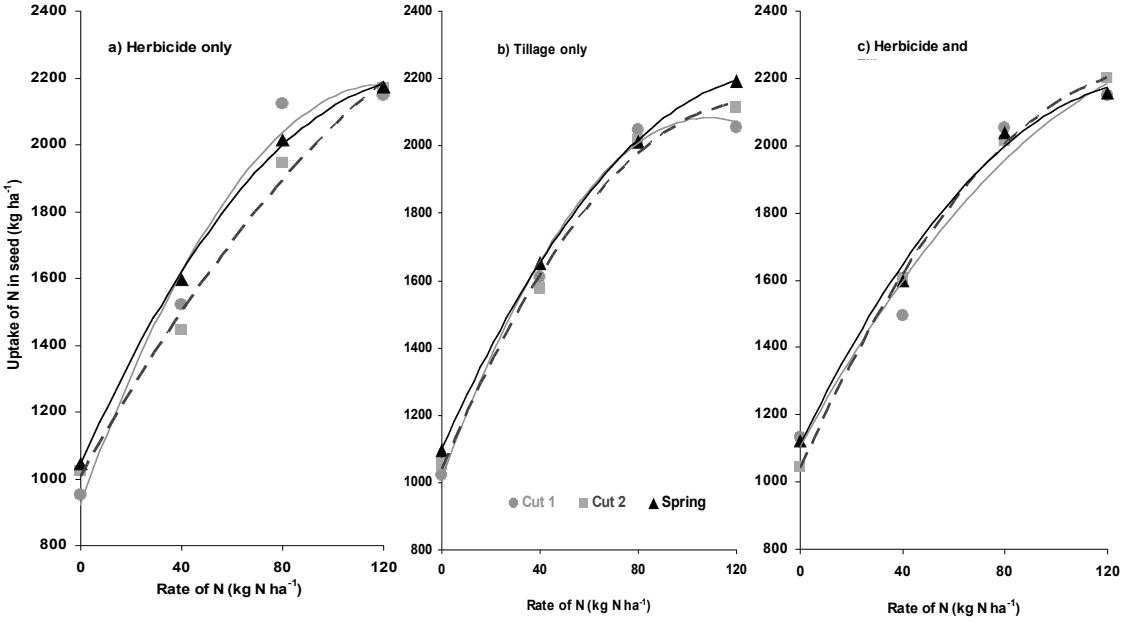

Figure 12. Seed yield of Canola for termination method x termination time x rate of N in 2007.

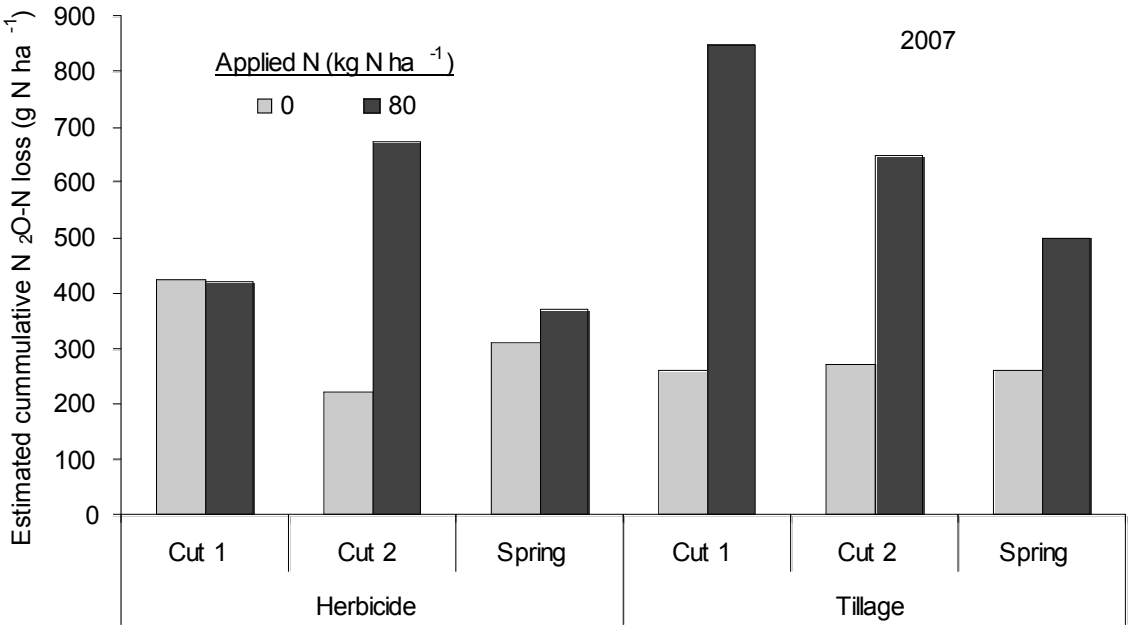

Figure 13. Estimated cumulative N_2O-N emissions in the zero-N and 80 kg N ha^{-1} treatments for 2 termination methods and 3 termination times in 2007.

Summary of results

Soil Organic C and N, and Mineral N in Autumn 2007

After 4 Years

- TOC, TON, LFOC and LFON after four growing seasons were usually higher or tended to be higher under herbicide (no-till) than tillage treatment in the 0-5 cm layer, but the opposite was true in the 5-10 and 10-15 cm layers. Soil organic C and N also increased with N fertilization.
- In autumn 2007, there was no significant effect of termination time and method, and n rate on soil ammonium-N or nitrate-N.

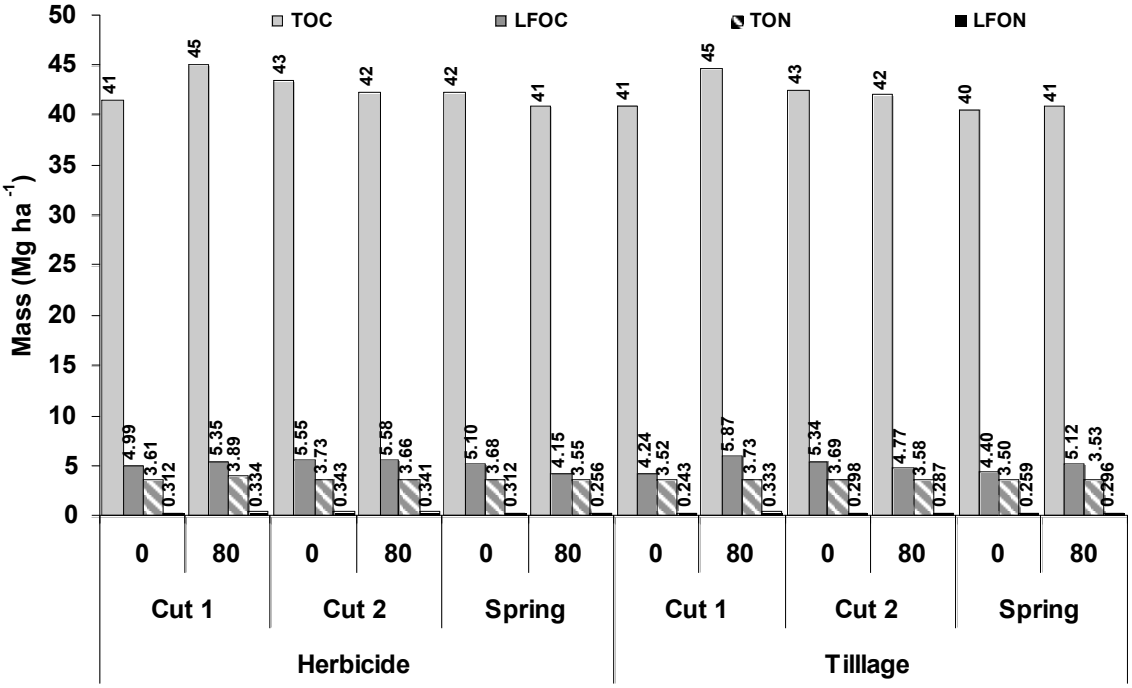

Figure 14. Total organic C (TOC) and N (TON), and light fraction organic C (LFOC) and N (LFON) in 0-15 cm soil in autumn as affected by termination method, termination time and N fertilization in autumn 2007.

Conclusions

- Overall, the results suggested that in the first crop year after alfalfa stand termination, N fertilization can be used to compensate for the decline in yield due to the delay in alfalfa stand termination, especially when herbicide method is used.
- The effect of termination performed in summer 2003 or in spring 2004 diminished substantially in the second cropping season, and nearly disappeared by the third cropping season.
- There was delayed release of mineral N in untilled soils, so herbicide (no-till) termination may reduce the potential for nitrate N loss to the environment.
- The herbicide termination method had the lowest N_2O-N loss in the termination year or in the first crop year following termination, while tillage had the highest N loss. When considered on a cumulative basis over a 3 or 4 year period, the N_2O-N loss was not affected by method or timing of termination.
- Overall, herbicide (no-till) and N fertilization had or tended to have positive effect on organic C and N, especially light fraction organic C and N.

Acknowledgements

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