Nitrogen Fertilization Management for No-Till Cereal Production in the Canadian Great Plains

S. S. Malhi[1], A. M. Johnston[2] and C. A. Grant[3]

[1]Agriculture and Agri-Food Canada, Research Farm, P.O. Box 1240, Melfort, Saskatchewan, Canada S0E 1A0
(Tel: 306 752 2776 Ext.230; Fax: 306 752 4911; Email: malhis@agr.gc.ca);
[2]Potash and Phosphate Institute of Canada, Suite 704, CN Tower, Midtown Plaza, Saskatoon, Saskatchewan, Canada S7K 1J5; and
[3]Agriculture and Agri-Food Canada, Research Centre, P.O. Box 1000A, Brandon, Manitoba, Canada R7A 5Y3

BACKGROUND

- As N is the nutrient most limiting crop production in vast areas of the world, its effective and efficient use is essential for long-term sustainability of crop production, and soil and environmental quality.
- Fertilization must ensure that an adequate amount of N is available when required by the crop, crop damage is avoided or reduced to a minimum, N losses are minimized, nutrient use efficiency (NUE) is maximized, and crop yield is optimized without leading to negative effects on crop, soil or environmental quality. In addition, the operation must be efficient in terms of both time utilization and economics.
- An effective and efficient N management program deals with four main issues, *i.e.*, rate, source, timing and placement. These options can be combined into many effective management packages and the “best” fertilizer management package for a particular farm will vary, depending on crop grown, soil type, environmental conditions and other constraints within the overall production system.
- The widespread adoption of reduced tillage systems in the Canadian Great Plains has led to a requirement for improved understanding of the impact of tillage on N dynamics and fertilizer use efficiency. When tillage intensity is reduced, crop residue from previous crops stays on the soil surface, which also affects soil properties

OBJECTIVE

- The objective of this poster is to summarize research information from various experiments conducted in the Prairie Provinces of Canada related to N fertilization management for no-till cereal production to illustrate the management practices which can be used to optimize the N use efficiency so as to optimize crop yield and minimize the N loss from root zone and environmental damage.
- The indicators considered are stand density/emergence, seed yield, straw yield, seed quality (protein concentration), N-use efficiency (seed yield per unit of applied N), N uptake, N uptake index (seed yield per unit of N uptake or uptake of N per kg of seed yield), recovery of applied N, economic returns (net present value – NPV), soil moisture, penetration resistance, aggregation, ammonium-N, nitrate-N, nitrous oxide emissions.

SUMMARY AND CONCLUSION

Soil Properties:

- **Soil Moisture:** Mulch and standing stubble preserved under ZT increases water retention (and snow), and soil moisture content is generally higher under ZT than under CT. **Figure 1.**
- **Soil Temperature:** Soil covered with crop residue and standing stubble is generally cooler during spring and summer, but stays warmer during autumn and winter **Figure 2.**
- **Soil Bulk Density and Penetration Resistance:** Surface bulk density (reflected in penetration resistance) increases under ZT compared to CT. **Figure 3.**
- **Soil Aggregation:** Elimination of tillage and residue retention increase soil aggregation, and this may also increase the ability of the soil to retain moisture. **Figure 4.**
- **Soil Nitrate-N:** ZT (especially with retention of crop residues at the soil surface) slows nitrate-N release and reduces the amount of N readily available for the crop in a given season. Lower mineralization under ZT may reduce potential for nitrate-N loss by denitrification and leaching, and consequently result in more conservation of soil N. **Figure 5.**
- **Soil Organic C and N:** ZT, particularly in combination with residue retention, was found to increase soil organic C and N. This increases N supplying power of soil, in addition to improving soil structure (aggregation), tilth, water retention and aeration, and reduces the potential for soil erosion. **Figure 6.**
- **Nitrous Oxide (N_2O) Emissions:** The N_2O emissions from soil were found lower under ZT compared to those under CT. Thus, ZT system has potential for reducing greenhouse gas emissions in the Parkland region. **Figure 7.**

Crop Yield, N Uptake and N Recovery:

- **Soil N Supply and Fertilizer Use Efficiency:** Reduced tillage decreases the supply of N from soil (**Figure 5**) and this may increase the requirement for N input into the system. This may also change fertilizer use efficiency due to changes in microclimate, microbial activity, and distribution of fertilizer relative to crop residue.
- **Broadcast Application of N:** Broadcast application of urea or other N fertilizers is less effective and efficient under ZT than CT. This is because that under ZT broadcast N fertilizer remains on the surface until moved into the soil by precipitation, and also applied. When urea is applied to the surface, NH3 can be lost to the atmosphere, leaving less N for plant uptake and makes it less efficient than non-urea fertilizers. Surface-applied NO_3-based fertilizers enhanced plant recovery of ^{15}N more compared to urea and ammonium sulphate (AS) under both ZT and CT, with differences greater under ZT than CT. **Figures 8 and 9**.
- **In-Soil N Fertilizer Placement Methods:** Broadcast application of N fertilizer is less efficient under ZT than CT. Incorporation reduces the potential for NH_3 volatilization loss from urea by moving it below the soil surface, and this increases the benefits to be obtained from in-soil placement. Placing N fertilizer in concentrated bands (or large urea granules – LUG) reduces contact with soil microorganisms, reducing immobilization of applied N. Banding (more so with LUG) also slows the conversion of urea to NH_3 and NH_4 to NO_3, which reduces losses by denitrification and leaching. This leaves more N for crop uptake. Improved synchronization of crop demand with N supply can be obtained by

developing a combination of N rate, source, placement (including banding, nesting, large urea granules or seedrow-placement) and timing that is suited to the environment and the management system in use in the farming operation. **Figures 10, 11 and 12**.

- **Seedrow-Placement of Urea and Role of Urease Inhibitors:** The amount of seed-placed fertilizer that can be safely applied depends on a number of factors, including environmental conditions, crop grown, soil type, width of the seed/fertilizer band, row spacing and fertilizer source. Retention of urea in the urea form with the use of urease inhibitors (UI) with seed-placed urea fertilizer reduces seedling toxicity, and increases stand density and seed yield when high rates of N fertilizer are applied. The use of UI shows promise in improving the efficiency of surface-applied urea-containing fertilizers in no-till systems and reducing seedling damage from seed-placed fertilizers, but the cost of UI must be considered before using urea treated with UI on a commercial scale. **Figures 13, 14 and 15**.
- **Straw Effect:** Broadcast application of N is subject to immobilization, and this is particularly true in the presence of large amounts of high C:N ratio residue. Immobilization of N by straw may lead to reduced crop yield, N uptake and recovery of applied N, and response to higher N rates in the initial years compared to when straw is removed. Return of crop residues over time increases in the N-supplying power of the soil, so that immobilization in newly-applied residues is balanced by mineralization of soil organic matter, resulting in crop yield and economic returns similar or greater than straw removal at appropriate N rates. Volatilization loss may be greater when urea is applied to residue-covered soil, because of high urease activity associated with residue retention on the soil especially under ZT. The reduction of mineralization and immobilization of N by straw can be overcome by using optimum N rate, time of application and method of placement and beneficial effects like soil moisture conservation and improved soil tilth/quality results in better seed yield and returns. **Figures 16 and 17**.
- **In conclusion**, ultimately, any N fertilization package has advantages and disadvantages. Points to consider when selecting the optimum fertilizer management system for a farming operation: rate of application, cost and availability of equipment, soil disturbance, seedbed quality, moisture conservation, time constraints, labor constraints and fertilizer use efficiency. The "best" management system is not fixed, but depends on the major limiting factors on each individual farm.

ACKNOWLEDGEMENT

The authors acknowledge the technical help of Darwin Leach for preparing the poster and Ralph Underwood for printing the poster.

REFERENCES CITED

Grant, C.A., Brown, K.R., Racz, G.Z., Bailey, L.D., 2001. Influence of source, timing and placement of nitrogen on grain yield and nitrogen removal of Sceptre durum wheat under reduced- and conventional- tillage management. Can. J. Plant Sci. (in press).

Malhi, S.S., O'Sullivan, P.A., 1990. Soil temperature, moisture and compaction under zero and conventional tillage in central Alberta. Soil Tillage Res. 17, 167-172.

Malhi, S.S., Mumey, G., O'Sullivan, P.A. and Harker, K.N. 1988. An economic comparison of barley production under zero and conventional tillage. Soil Tillage Res. 11: 159-166.

Malhi, S.S., Bhalla, M.K., Piening, L.J., Caldwell, C., 1992a. Effect of stubble height and tillage on winter soil temperature in central Alberta. Soil Tillage Res. 22, 243-251.

Malhi, S.S., McAndrew, D.W., Carter, M.R., 1992b. Effect of tillage and N fertilization of a Solonetzic soil on barley production and some soil properties. Soil Tillage Res. 22, 95-107.

Malhi, S.S., Nyborg, M., Solberg, E.D., 1992c. Minimizing the effect of straw on the availability of fertilizer N to barley. In: Proceedings of Alberta Soil Science Workshop, 18-20 February 1992, Lethbridge, Alberta. pp. 136-139.

Malhi, S.S., Mumey, G., Harker, K.N., 1993. Economic comparisons between zero and conventional tillage as influenced by N fertilizer management. In: N. J. Burrow (Ed). Plant Nutrition - from Genetic Engineering to Field Practice. Kluwer Academic Publishers, Netherlands. pp. 559-562.

Malhi, S.S., Nyborg, M., Solberg, E.D., 1996. Influence of source, method of placement and simulated rainfall on the recovery of ^{15}N-labeled fertilizers under zero tillage. Can. J. Soil Sci. 76, 93-100.

Malhi, S.S., Oliver, E., Mayerle, G., Kruger, G. and Gill, K.S. 2003. Improving effectiveness of seedrow-placed urea with urease inhibitor and polymer coating for durum wheat and conola. Commun. Soil Sci. Plant Anal. 34: 1709-1727.

Malhi, S.S., Lemke, R. and Singh, B. 2006. Influence of tillage and crop residue management on crop yield, greenhouse gas emissions and soil quality. Soil Tillage Res. In Press.

Nyborg, M., Malhi, S.S., 1989. Effect of zero and conventional tillage on barley yield and NO_3-N content, moisture and temperature of soil in north-central Alberta. Soil Tillage Res. 15, 1-9.

Nyborg, M., Solberg, E.D., Malhi, S.S. and Izaurralde, R.C. 1995. Fertilizer N, crop residues and tillage alter soil C and N content in a decade. Pages 93-99. Adv. Soil Sci. *In:* Lal, R. et al. (eds.), Soil Management and Greenhouse Effect. CRC Press, Boca Raton, FL., U.S.A.

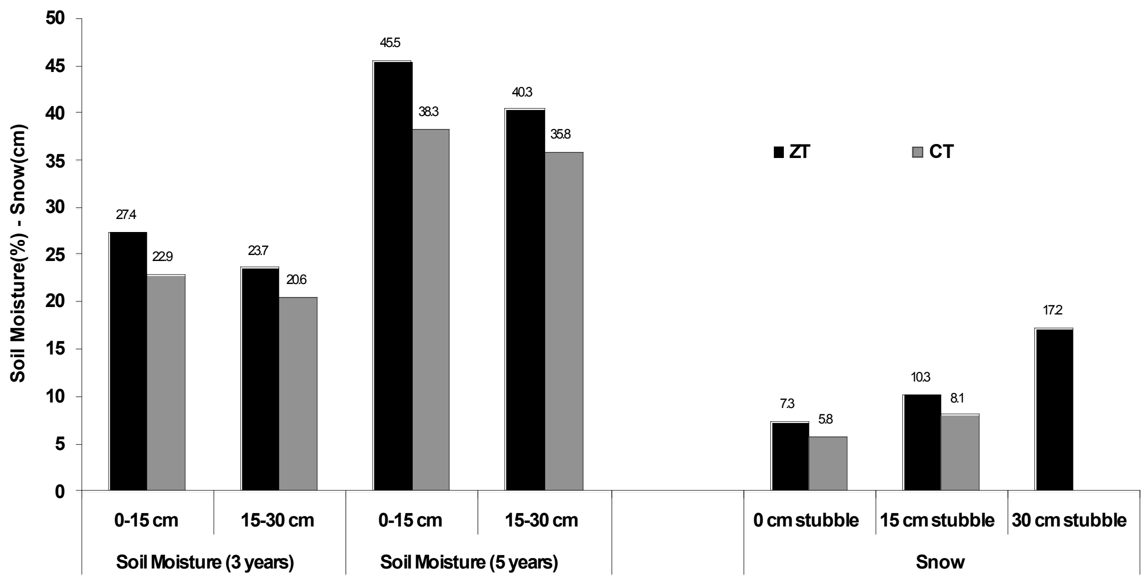

Figure 1. Tillage and crop residue management effects on soil moisture (average of 3 years - Malhi et al. 1992b) (average of 5 years - Malhi and O'Sullivan 1990) and snow depth (Malhi et al. 1992a).

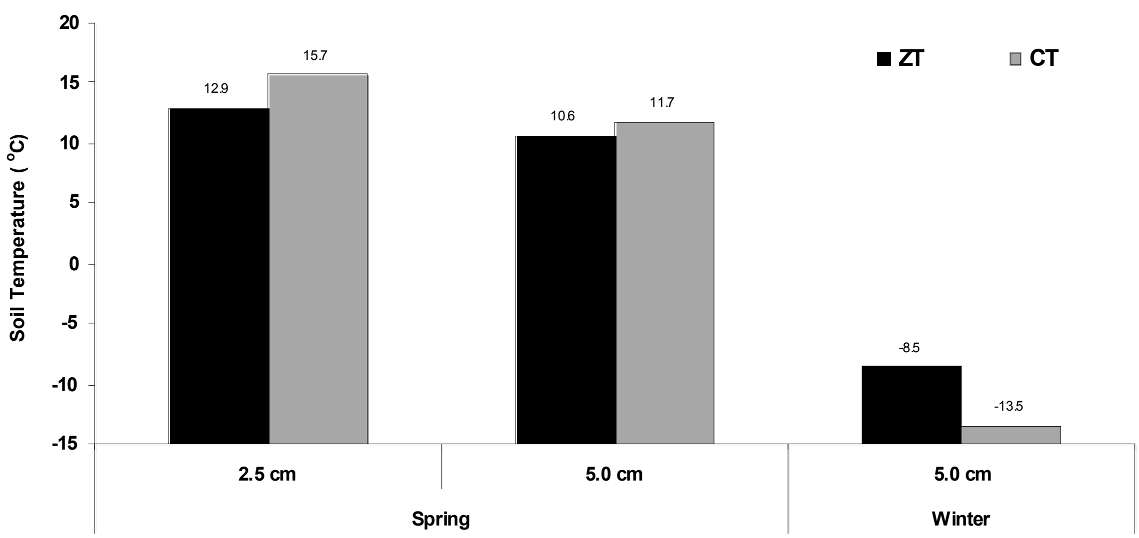

Figure 2. Tillage and crop residue management effects on spring soil temperature (average of 3 years - Malhi and O'Sullivan 1990) and minimum soil temperature during winter in zero-tillage system with 15 cm stubble height (average of 2 years – Malhi et al. 1992a).

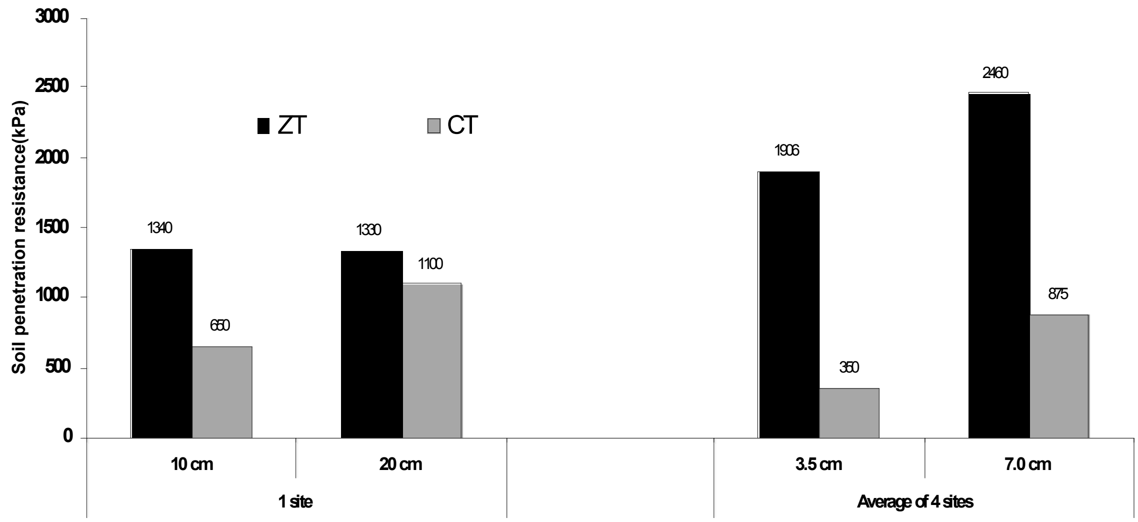

Figure 3. Tillage and crop residue management effects on soil penetration resistance at one site (Malhi et al. 1992b) and average of 4 sites (Malhi and O'Sullivan 1990).

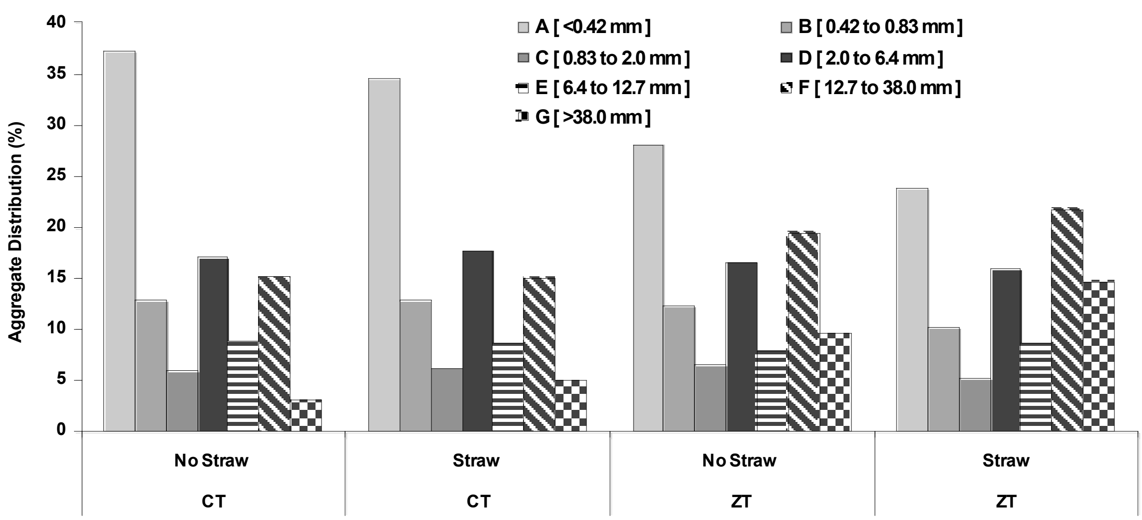

Figure 4. Effect of combination of conventional tillage [CT] and zero tillage [ZT] with straw removed and straw retained on soil aggregate distribution as a percentage of the total fractions after 4 crop years (Malhi et al. 2006. Soil Tillage Res. In Press).

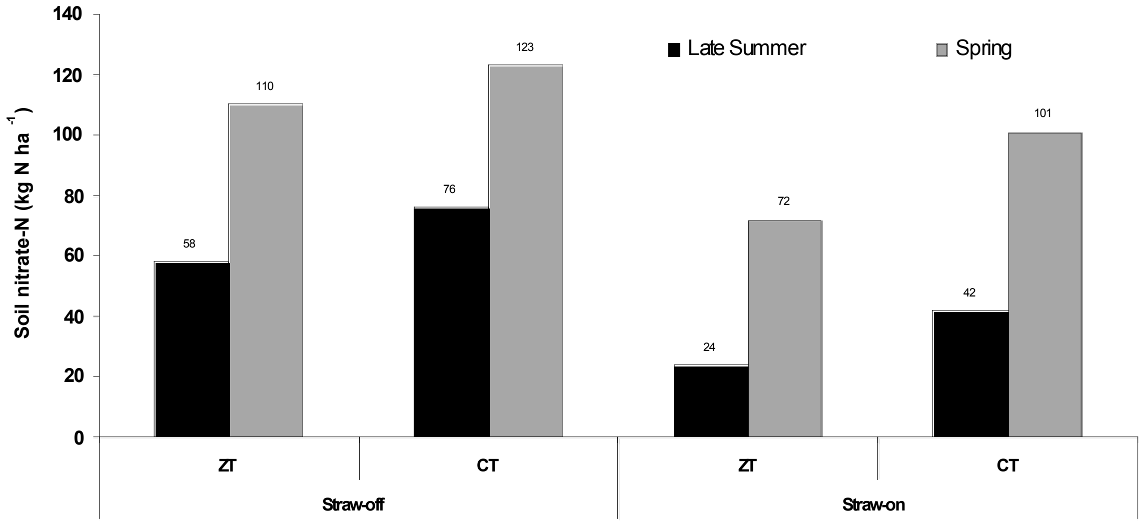

Figure 5. Nitrate-N (kg N ha^{-1}) in 30 cm summer fallow soil in zero-N control (average of 2 sites – Nyborg and Malhi 1989).

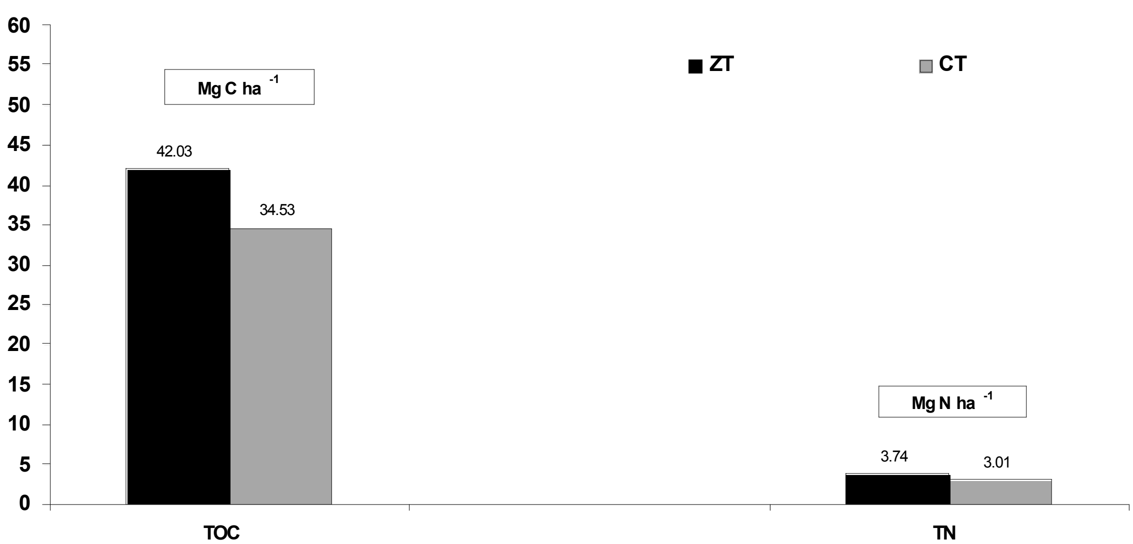

Figure 6. Total organic C (TOC) and N (TN) in the surface (15 cm) soil after 11 years of continuous treatment at Breton, Alberta. (Nyborg et al. 1995).

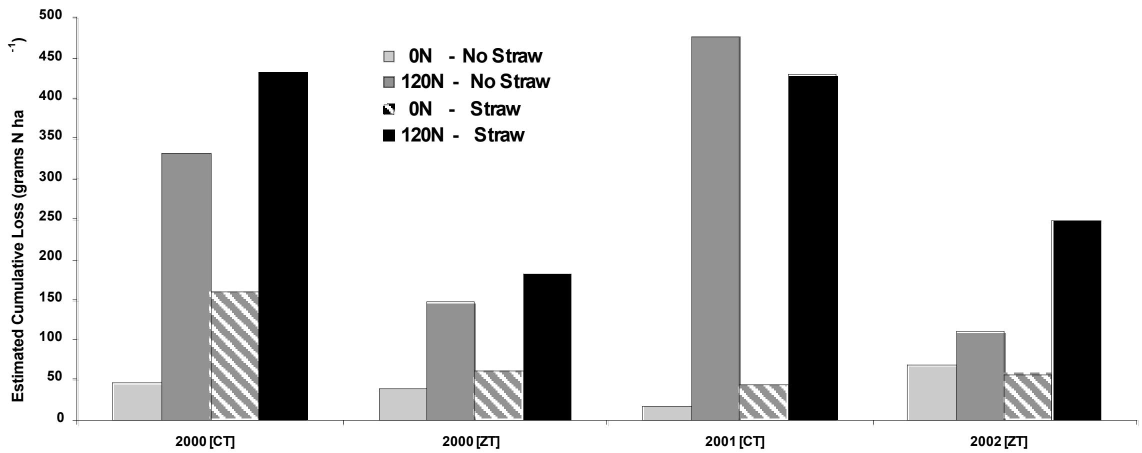

Figure 7. Estimated cumulative N2O-N loss for various treatments at Star City during the period March 28 to June 5 2000 and April 23 to August 9 2001 (Malhi et al. 2006. Soil Tillage Res. In Press).

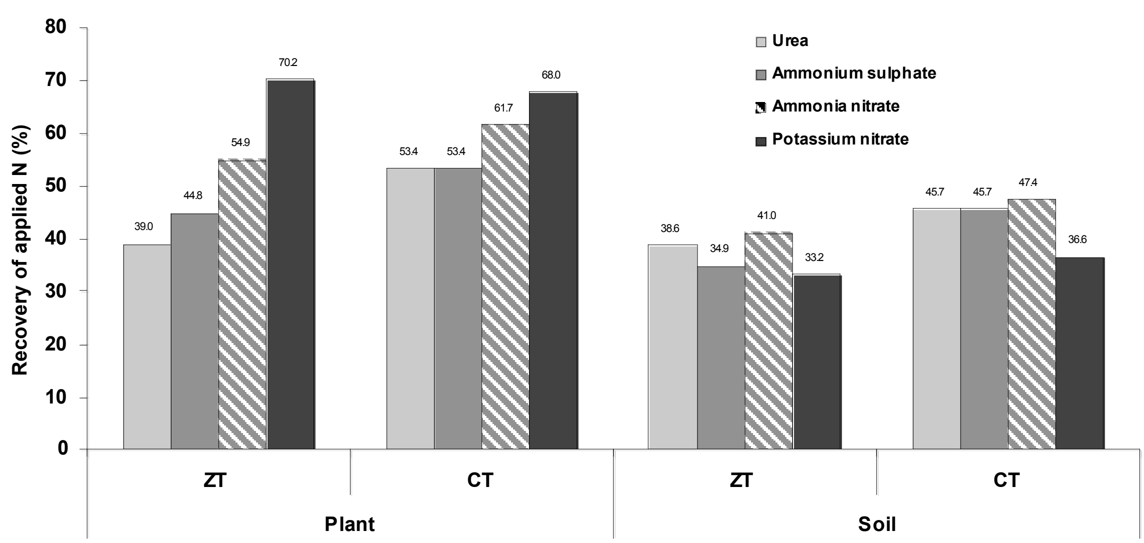

Figure 8. Influence of tillage and N source on the recovery of ^{15}N-labelled fertilizers applied to barley (broadcast) in Alberta (average of 2 sites) (Malhi et al. 1996).

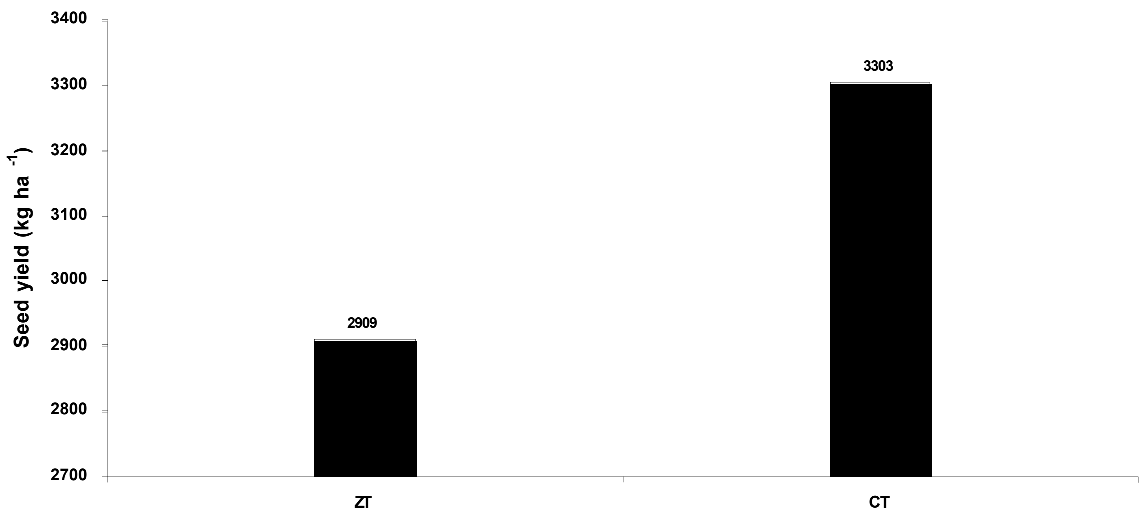

Figure 9. Influence of tillage on seed yield of barley with broadcast urea (average of 4 sites) (Malhi et al. 1988). Net loss ($ ha^{-1}) for ZT compared to CT ranged from -$32.00 to -$99.00 for field operating cost factor of 0.50 to 1.25.

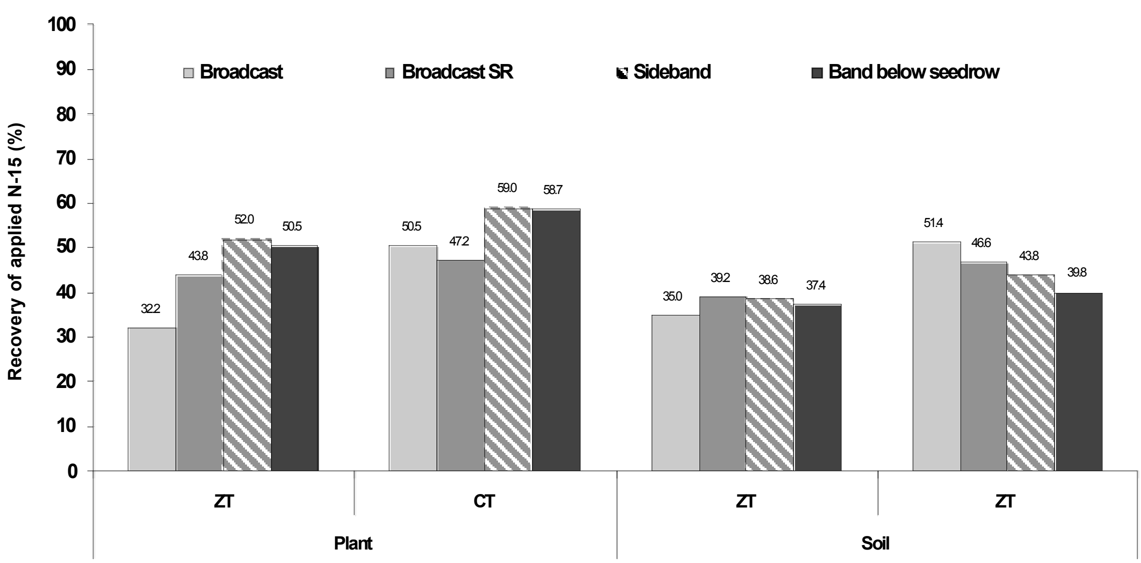

Figure 10. Influence of tillage and placement method on recovery of applied ^{15}N-labelled urea (simulated rainfall of 10 cm) (average of 2 sites – Malhi et al. 1996).

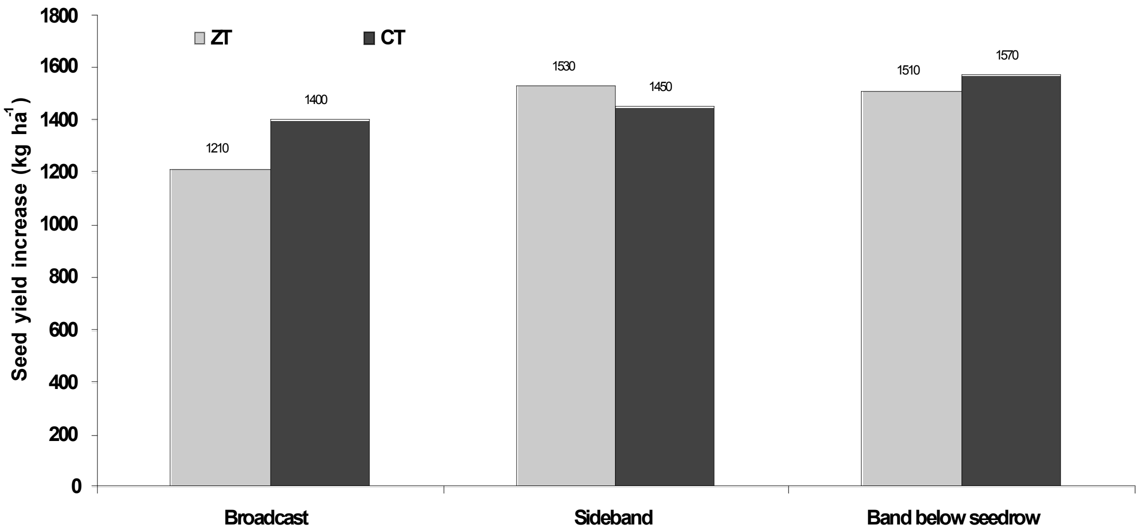

Figure 11. Influence of tillage and placement method of urea on seed yield increase (Malhi and Nyborg 1992b).

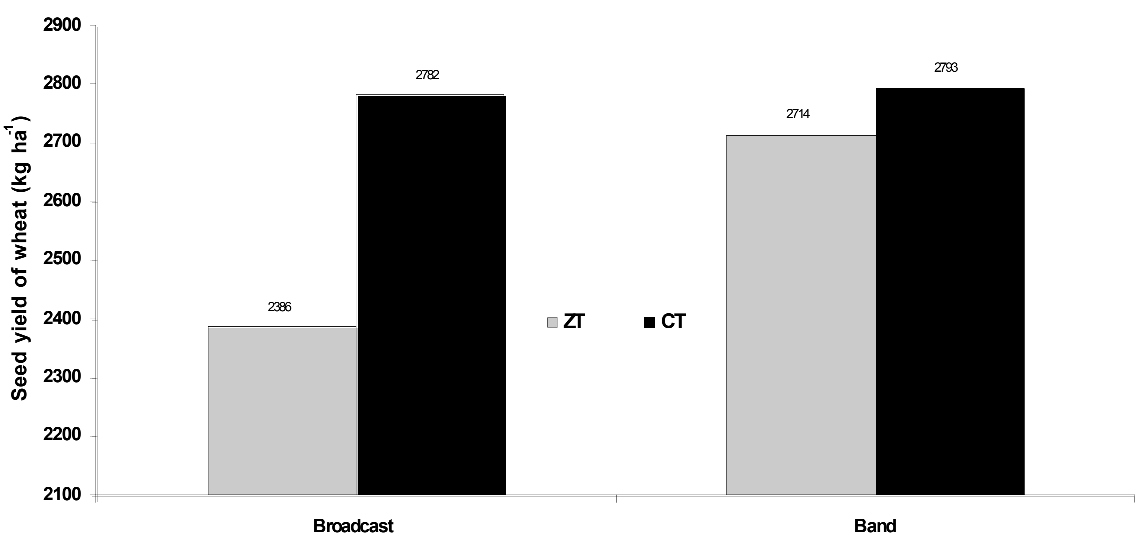

Figure 12. Influence of tillage and placement method of urea on seed yield of wheat (average of 2 sites) (Grant et al. 2001).

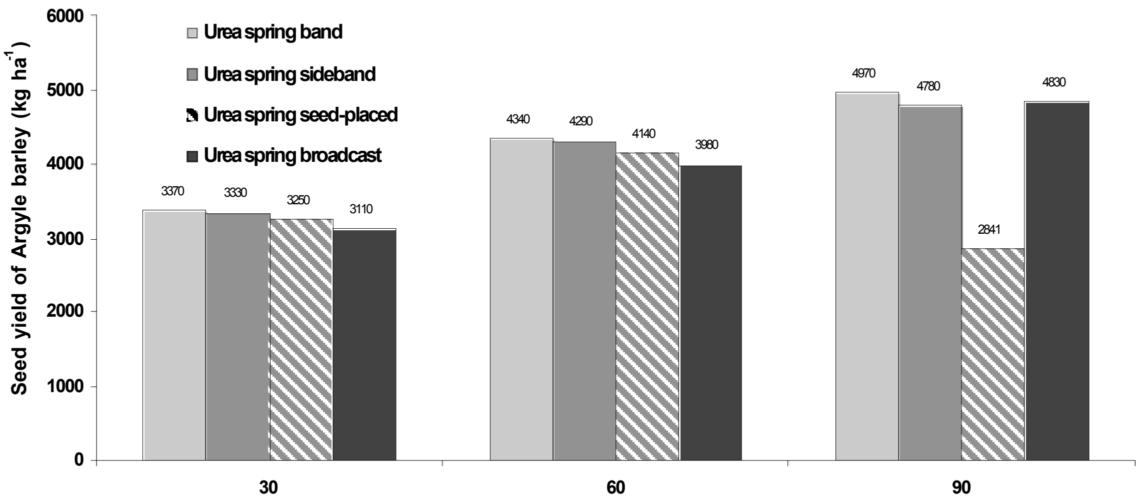

Figure 13. Grain yield of Argyle barley (average of 3 years) under reduced tillage as influenced by method of placement of 30, 60 and 90 kg N ha^{-1} of urea on a Orthic Black Chernozem (Frigid Typic Hapludoll) soil in Manitoba (C.A. Grant 1997 – unpublished results).

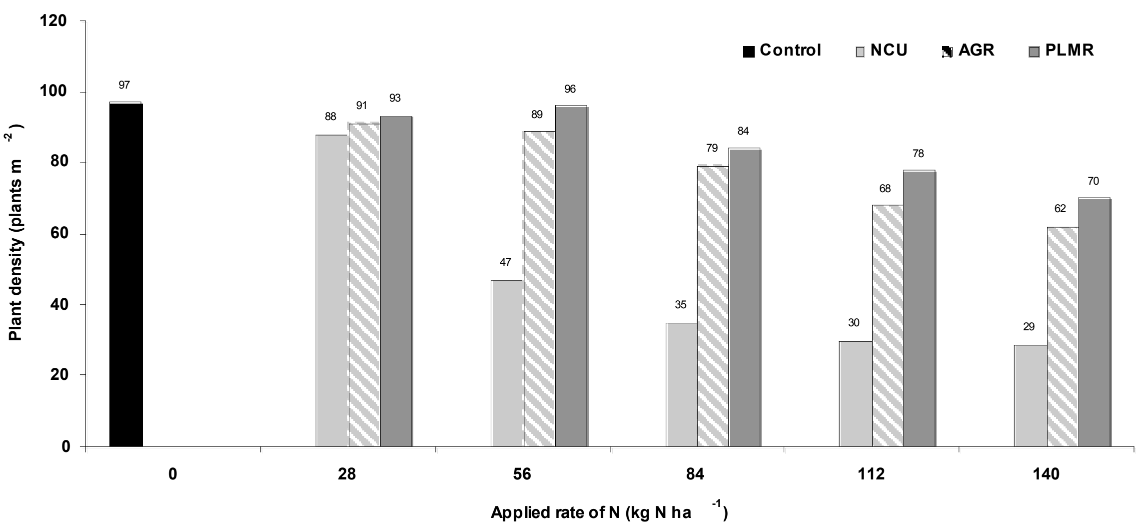

Figure 14. Influence on emergence using Agrotain (AGR), Polymer coating (PLMR) and standard urea (NCU) seed-row placed on wheat. (Malhi et al. 2003).

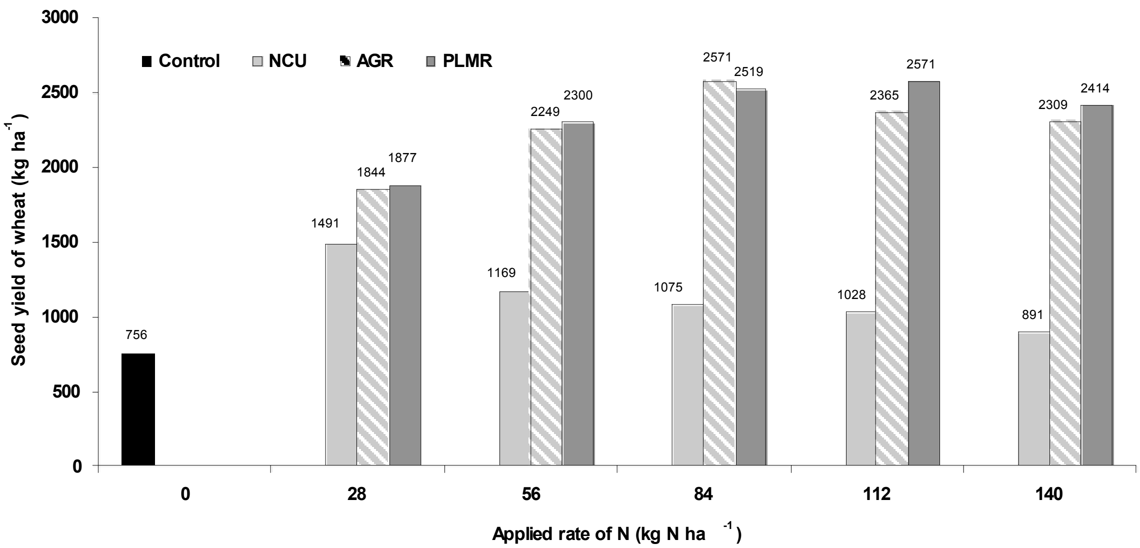

Figure 15. Influence on seed yield using Agrotain (AGR), Polymer coating (PLMR) and standard urea (NCU) seed-row placed on wheat. (Malhi et al. 2003).

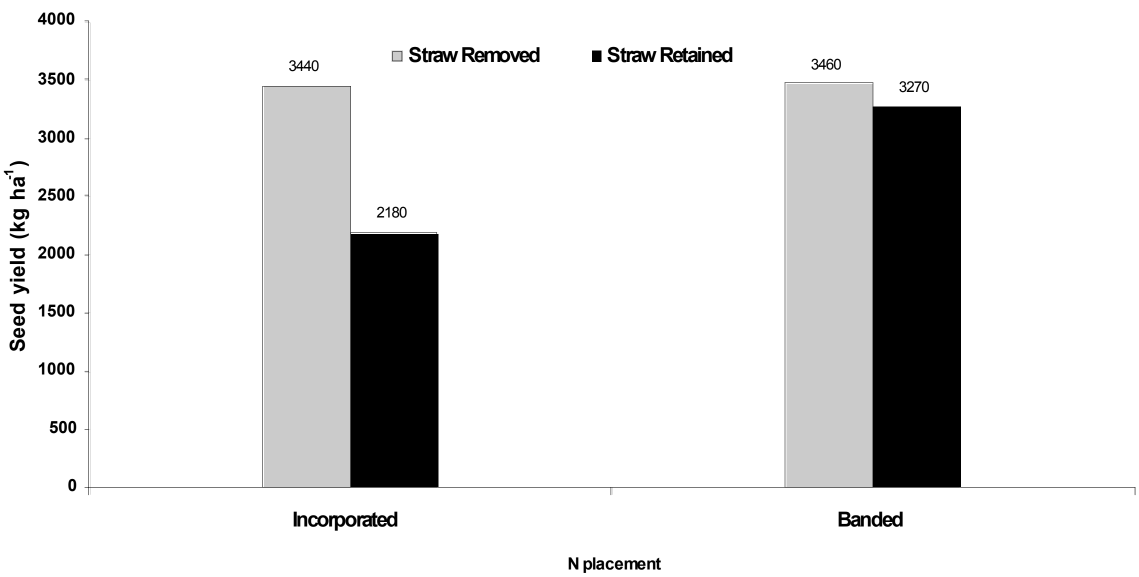

Figure 16. Effect of straw management and placement method (banded was placed below seedrow) on seed yield (average of 2 sites) (Malhi et al. 1992c).

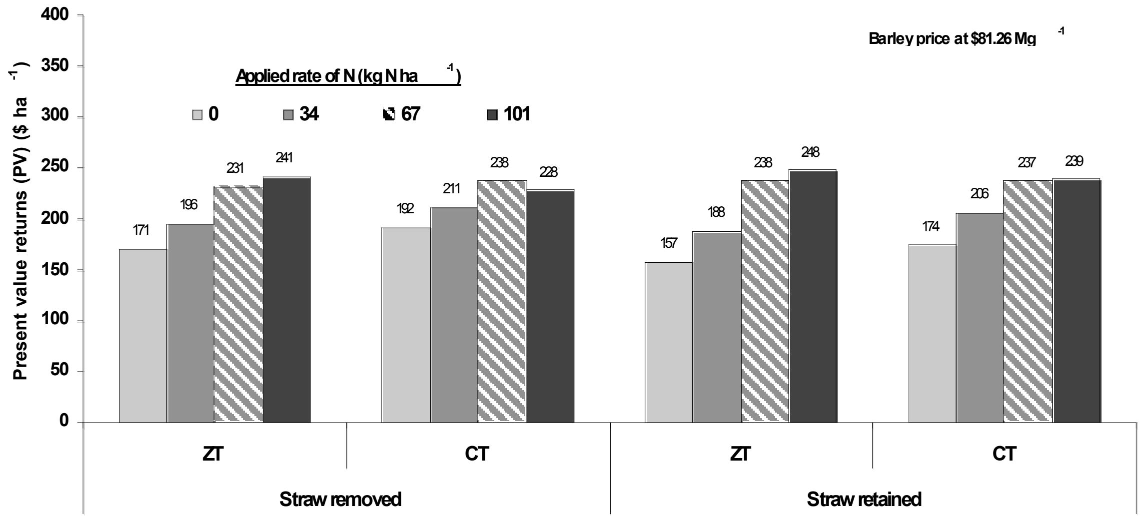

Figure 17. Influence of tillage, straw management and N rate with sidebanded urea on present value returns (PV returns) (average of 5 years and 2 sites) (Malhi et al. 1993).