Nitrogen Fertilization in Crop Production

Nitrogen fertilizers are most effectively used as part of a balanced fertilization plan that aims to maximize economic return and maintain environmental quality. Within the Canadian prairies, nitrogen (N) is most often the yield-limiting nutrient with respect to crop production. Nitrogen contributes firstly to grain yield and forage biomass production, and at the same time to protein. Once the yield requirements for nitrogen have been met, further nitrogen uptake, especially later in the season, contributes mostly to protein level increases. For an optimum economic response when applying nitrogen fertilizer, the nitrogen application rate needs to be balanced with moisture and the availability of other plant nutrients. Soil testing is critical to determining the appropriate rate of nitrogen fertilizer to apply to match crop yield potential. This helps determine the availability of nitrogen along with other nutrients and the assessment of stored soil moisture.

In the event of a crop failure, much of the nitrogen left unused in the soil, under Saskatchewan weather conditions, can carry into the following season and can be accounted for by a soil test. Table 1 shows the nitrogen uptake by crops grown in Saskatchewan.

Table 1. Nitrogen taken up by various Saskatchewan crops.

Crop	**Yield bu./ac.**	**Grain lbs. N/ac.**	**Straw lbs. N/ac.**	**Total Uptake lbs. N/ac.**	**Total Uptake lbs. N/bu.**
Spring Wheat	40	54 - 66	22 - 27	76 - 93	1.9 – 2.3
Winter Wheat	50	47 - 57	14 - 17	61 - 74	1.2 – 1.5
Barley	80	70 - 85	30 - 37	100 - 122	1.3 – 1.5
Oats	100	55 - 68	41 - 49	96 - 117	1.0 – 1.2
Corn	100	87 -107	51 - 61	138 - 168	1.4 – 1.7
Canola	35	61 - 74	39 - 49	100 - 123	2.9 – 3.5
Flax	24	46 - 56	18 - 22	64 - 78	2.7 – 3.3
Sunflower	50	48 - 59	19 - 23	67 - 82	1.3 – 1.6
Lentils*	30	55 - 67	27 - 34	82 - 101	2.7 – 3.4
Peas*	50	105 - 129	33 - 39	138 - 168	2.8 – 3.4
Fababeans*	50	154 – 188	103 -157	257 - 314	5.1 – 6.3
Soybeans*	30	112 - 120	26 - 54	138 -174	4.6 – 5.8
Alfalfa* hay	2.5 tons			131 - 160	52.2 – 63.8 lbs. N/ ton
Grass hay	1.5 tons			46 - 56	30.7 – 37.7 lbs. N/ton

*Pulse and legume crops are inoculated with specific strains to fix nitrogen.
Source: Nutrient Uptake and Removal by Field Crops – Western Canada; Canadian Fertilizer Institute.

Yield

For dryland annual crops grown on the prairies, much of the nitrogen uptake that contributes to yield occurs in the first few weeks following germination, and is complete after about two months (Figure 1). Maximum nutrient uptake occurs earlier than maximum biomass production. After maximum biomass is achieved, for the growing conditions of that year, nitrogen uptake contributes mainly to protein content.

The response of grain yield to nitrogen fertilization depends greatly on moisture. Improved moisture usually means more yield to a point where some other limiting factor comes into play. Excess moisture can result in reduced yield due to leaching losses of nitrates, as well as the loss of nitrates by conversion (denitrification) to gases that escape from the soil. High levels of available soil nitrogen early on in the growing season can promote heavy vegetative growth and water use.

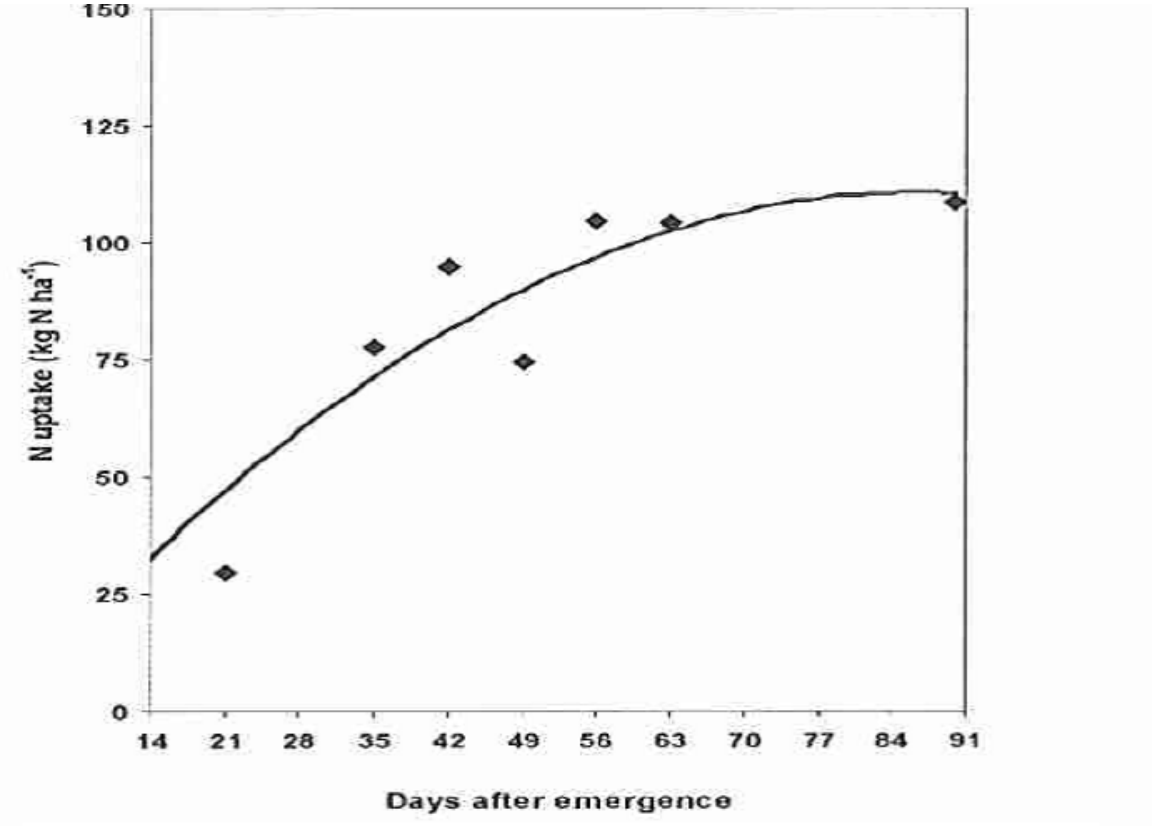

Figure 1. Changes in nitrogen uptake of cereals with days after emergence in the field experiment at Melfort (Malhi et al, 2004).

Protein

Additional nitrogen usually results in higher grain protein content. Under conditions of extreme nitrogen deficiency, a small amount of added nitrogen may result in no protein increase, or even a small decrease, due to dilution from the large growth enhancement associated with the added nitrogen. Beyond this point, increased soil nitrogen supplies are normally associated with increased protein content (Figure 2). Timing of moisture is important and in particular the

extent and duration of any moisture stress. Moisture stress at flowering can lower yield but increase the protein content.

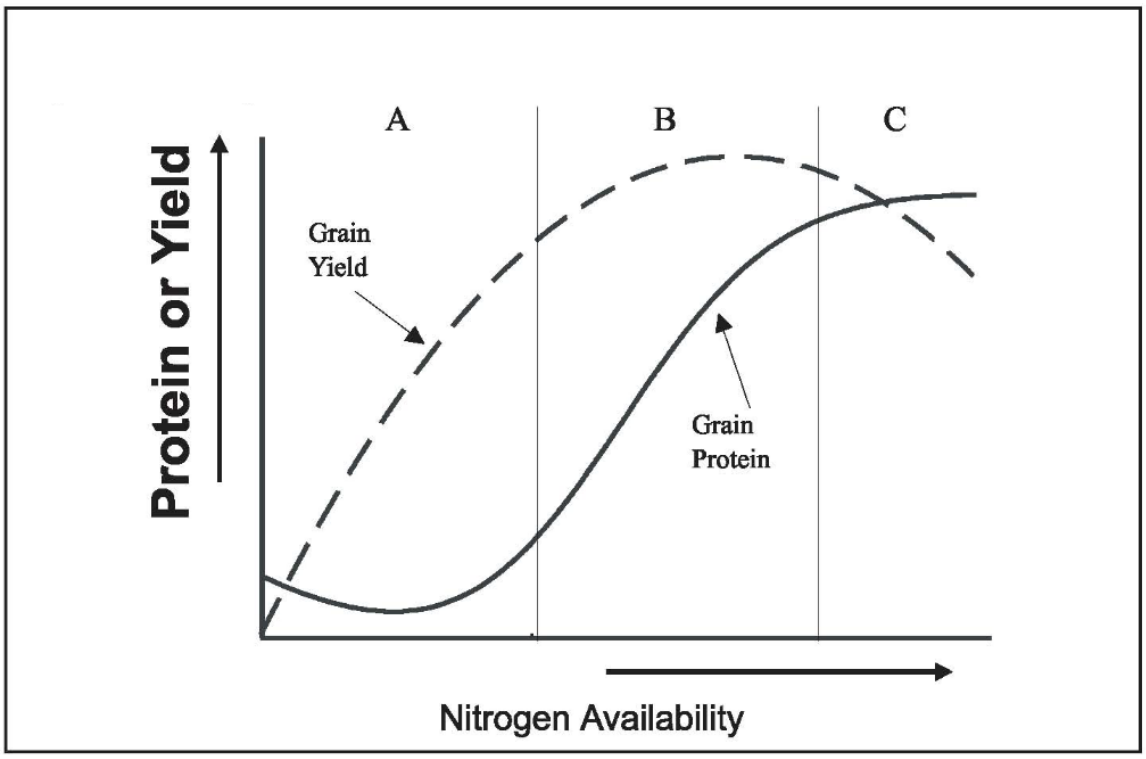

Figure 2. Ideal yield and protein response to N availability (adapted from Selles et al, 1997).

Nitrogen Fertilizer Sources

Forms of nitrogen fertilizer widely available and used in Saskatchewan include granular urea (46-0-0), anhydrous ammonia (82-0-0) and urea ammonium nitrate (UAN) solutions (28-0-0) (Table 2). Coated granular nitrogen fertilizer products are also available that provide a controlled release of available nitrogen (44-0-0).

Other fertilizer products that serve as sources of nitrogen as well as other nutrients include ammonium sulfate (21-0-0-24), mono-ammonium phosphates (11-52-0) and ammonium phosphate sulfate (16-20-0-14), ammonium polyphosphate (10-34-0) and ammonium thiosulphate (15-0-0-20). Several complete low-analysis starter fertilizers also provide some nitrogen for early crop growth. Animal manures and composts are also valuable sources of nitrogen along with other nutrients. The low and often variable content of available nitrogen in animal manures requires special considerations in their use.

Fertilizers that contain or produce ammonium result in acidity when ammonium is converted to nitrate in the soil. In most Saskatchewan soils, this is not an issue. However, it may be of concern in some sandy, acidic soils.

Application

Nitrogen fertilizers can be permanently lost through ammonia volatilization, denitrification, leaching and run-off. Nitrogen may also be temporarily tied-up in the soil organic matter by microorganisms (immobilization), especially when the fertilizer is closely associated with crop residues of low nitrogen content. A rule of thumb is that potential losses of nitrogen fertilizer will be reduced the closer the fertilizer is applied to the time of crop use. Late fall (after the soils have cooled below 10 degrees C) or spring, pre-plant banding of anhydrous ammonia or urea can be efficient, depending on soil and climatic conditions. However, applications made as a band at the time of seeding are often the most efficient in increasing yield. In general, the application of nitrogen fertilizer in-soil, especially in a band, reduces potential losses compared to surface application. Urea containing fertilizers, including some manures, are susceptible to ammonia volatilization losses when surface applied and not incorporated.

There has been increasing use of surface application of solution 28-0-0 nitrogen fertilizer in a dribble band. Surface placement of nitrogen fertilizer, whether in a band or broadcast, will work best if there is a rain following application, which moves the fertilizer into the root zone.

When surface application is the only placement option, urea-containing fertilizer (46-0-0 or 28-0-0) may be treated with a urease inhibitor prior to use in order to reduce ammonia volatilization losses. The urease inhibitor will prevent the release of ammonia gas from the urea for a period of about two weeks (see product label for application rates and times of inhibition), giving an opportunity for the urea to be moved into the soil by rainfall over this period.

As a nitrogen management tool, polymer-coated urea (ESN 44-0-0) is widely available and provides controlled release characteristics by virtue of its polymer coating. The controlled release urea can be used for: placement options during seeding of winter cereals, used in seed-row placement to reduce the risk of seedling damage, and used in application environments that are conducive to nitrogen loss. Generally, wetter conditions that favour loss of nitrogen are a good fit for ESN. Surface broadcast application of ESN is subject to immobilization (temporary tie-up by the decomposing crop residue on the surface). Also, specialty crops like: potatoes, corn, fruits and vegetables may also benefit from this technology. Consult the product label and retailer for more details and uses.

Application of all the nitrogen fertilizer at the time of seeding in a single pass (direct seeding) is a common practice in Saskatchewan. Placing nitrogen fertilizers in the seed-row is a good method provided the rates are kept low. There is a limit to how much fertilizer nitrogen can be safely placed in the seed-row before injury in the form of reduced germination and emergence occurs. Such injury is due to the salt effect of the fertilizer holding back moisture from the seed and seedling, as well as ammonia toxicity produced from the urea fertilizer. The maximum safe rates of seed-placed nitrogen will vary with the opener spread and row spacing of the seeder, the crop, the soil texture and moisture (the fact sheet *Guidelines for Safe Rates of Fertilizer Applied with the Seed* should be followed to avoid damage).

To reduce or eliminate risk of crop damage when applying high rates of nitrogen fertilizers at the time of seeding, separation of the seed from the fertilizer is needed. This may be accomplished by placing the fertilizer in a separate channel from the seed. Various equipment

configurations are available to do this. Common separation strategies are placement of the fertilizer band one inch below and one inch to the side or banding in positions more than one inch to the side of the seed-row (side-banding) and placement of the fertilizer band midway between the seed-row (mid-row banding). Excessive travel speed and opener wear can result in poor seed and fertilizer separation. This can also be the case for opener configurations where fertilizer bands are placed near the seed row.

Blocked nitrogen applicator showing nitrogen deficient wheat.
Photo by International Plant Nutrition Institute.

Research in Saskatchewan has shown relatively little difference in agronomic performance of nitrogen fertilizer applied either as anhydrous ammonia or urea at seeding time in mid-row or side band configurations. Unlike phosphorus, nitrogen is considered a “mobile” nutrient in the soil and can move long distances with water moving to the roots. As a result, placement close to the seed is not considered essential for early crop access to nitrogen. However, under conditions of severe deficiency and when nutrient mobility in soil is limited, some nitrogen placed close to or in the seed row can be beneficial to ensure early nitrogen nutrition.

Granular fertilizers can be applied in the seed-row or banded in a separate furrow at the time of seeding, but anhydrous ammonia should never be placed where the ammonia can come into contact with the germinating seed or seedling. Liquid nitrogen fertilizers like 28-0-0 may be placed in the soil in furrows separate from the seed in a manner similar to other forms, and similar restrictions apply as to safe rates of nitrogen in close proximity to the seed. However, with the liquid forms, separation may be more easily achieved by “squirting” (directed flow liquid) the fertilizer away from the seed.

Applications of nitrogen fertilizer may also be made after crop emergence. Such applications may be made as a “rescue treatment” when nitrogen deficiency in the crop is detected by visual observation, tissue testing or using optical sensor technology. For most annual crops, early application will result in the best yield recovery, while delayed application will mainly

increase nitrogen concentration and protein in the plant. Top dressing is not generally recommended as the primary method of nitrogen application. However, it can be used when sufficient nitrogen was not applied before or at seeding, when additional nitrogen is warranted due to improved moisture conditions, or when applying nitrogen to increase grain protein content.

The fertilizer industry promotes sustainability and stewardship through awareness and adoption of beneficial management practices that will utilize the 4R (Right Source @ Right Rate, Right Time, Right Place®) Nutrient Stewardship System (4Rs) to increase production and profitability of farmers, while enhancing environmental protection and improving sustainability.

For more information:
Contact your Regional Crops Specialist; or
Call the Agriculture Knowledge Centre 1-866-457-2377.

Table 2. Common Commercial N Fertilizer Forms in Saskatchewan

Common formulations and usage in Saskatchewan	Reaction in soil	Physical properties of the fertilizer	Comment
Dry granular			
46-0-0 urea (NH2) CO 2 - Most commonly used source of N.	- Salt index* is 1.62. - Urea converts to ammonia in presence of urease enzyme. - Ammonia then converts to ammonium in presence of water (during this reaction the soil pH around the granule site is raised temporarily). - Ammonium is held on the soil with small amounts in the soil water. - Plants use both ammonium-N and nitrate-N.	- Granular. - Soluble in water. - Bulk density, non-compacted about 47 lb./ft.3. - Melting point is 133°C. - Critical relative humidity (RH) at which the fertilizer starts absorbing moisture is 73%.	See Guidelines For Safe Rates Of Fertilizer Applied With the Seed for banding with the seed. - Addition of a urease inhibitor can slow the conversion of urea to ammonia for up to two weeks (see product label for AGROTAIN rates). - Most common method of application is banding into soil (the furrow must be closed to prevent ammonia escape).
21-0-0-24; 20-0-0-24; 19-2-0-22 Ammonium sulphate (NH4)2SO4 - Most commonly used plant available form of S.	- Salt index is 3.25. - Sulphate remains in the soil water and is mobile.	- Granular or crystal. - Critical RH is 79%.	- Fertilizer sulphur is expressed as S. - Sulphate-S (SO4 -2) is the plant available form of S.

Gas - (liquid when compressed)			
82-0-0 - anhydrous ammonia - NH3 - Second most commonly used source of N.	- Salt index is 0.57. - Ammonia gas reacts with soil water to form ammonium. - Ammonium is held on the soil with some in the soil water.	- Compressed gas. - Sharp pungent odor. - Soluble in water. - Is a liquid at -33°C at one atmosphere of pressure.	- Free ammonia in soil is very toxic and can move through cell walls, injuring plant tissue. - Must be banded into moist soil and the furrow must close to prevent ammonia loss. - For side banding, if the seedbed is fractured because of poor seedbed conditions, ammonia can move into the seed row, injuring seed or seedlings. - It is important to understand and comply with all required safety and labeling guidelines.
Liquid - (solution-N fertilizer)			
28-0-0 - 50% urea-N, 25% ammonium-N, 25% nitrate-N. - Increasing use.	- Salt index is 2.3. - The urea fraction is subject to volatile losses. **	- Has a specific gravity of 1.3 at 15.6°C. - One imperial gallon weighs 13 lb. - Each imperial gallon contains 3.57 lb. of N. - pH is 7.0 to 7.6. - Salt out temperature is -18°C. - Must be above 0°C to be pumped. - Can be blended with other liquid fertilizers (P, K, S) in the spring for immediate application.	- Liquid fertilizers used in the seed row must follow the same guidelines as for granular fertilizer. See Guidelines For Safe Rates Of Fertilizer Applied With Seed. - Blended liquid fertilizers can provide all the nutrient needs for a crop, or liquid fertilizer system can be used in combination with granular or anhydrous ammonia fertilizer systems. - Can also be applied in irrigation water (fertigation). - Can be banded into the soil, spoke injected, dribble banded on the surface, foliar sprayed (keep N rates low for foliar spray application, water volumes high, apply into evening and/or under cool weather conditions to avoid leaf scorch). - Addition of a urease inhibitor (AGROTAIN) can slow the conversion of the urea portion of the fertilizer to ammonia for up to two weeks (see product label for AGROTAIN rates).

* Salt index is a measure of the salt effect that the fertilizer induces in the soil solution due to the affinity for water. The higher the salt index number, the greater the salt effect. Based on 20 lb. of actual nutrient N, P2O5, K2O, S.

** Volatile losses refer to volatilization of ammonia.