Fertilizer Best Management Practices

Fertilizer BMPs —

Suggested Practices for Semiarid North Dakota

By Tom Jensen, Adrian Johnston, David Franzen, and Jon Stika

We are hearing a lot about best (beneficial) management practices (BMPs) these days. Much of this interest in BMPs for agriculture is the increasing awareness that how we manage our soils and landscapes can have a large impact on the surrounding environment. As stewards of the land, northern Great Plains farmers have implemented soil conservation practices that exceed many other resource conservation activities in North America. The resulting reduction in wind and water erosion and moisture conservation have improved soils, and increased crop yields and whole-farm economics.

Fertilizer nutrients play a major role in meeting the crop yield and quality goals of modern agriculture. With reduced tillage seeding systems many semiarid regions have been able to extend crop rotations, reduced the use of fallow for moisture conservation, and increased the need to replace the nutrients removed by the increased cropping intensity. How we handle these fertilizer inputs provides the foundation for fertilizer BMPs and positive economic returns from fertilizer use.

BMPs focus on site-specific recommendations, intensive management, improved efficiency and environmentally sound use of crop production inputs. It is important that these management practices be proven in research and verified through field evaluation. It is also important to remember that BMPs are site-specific; they vary from one region to the next and one farm to the next depending on current and historic soil, climate and crop patterns and management expertise. Ultimately, it comes down to past research, farmer experience and the knowledge of the local soil and climatic conditions that dictate the success of a particular BMP in a specific field.

The way we handle fertilizers can have a major impact on the efficiency of nutrient use by crops and potential impact on the surrounding environment. In all instances we are striving to improve fertilizer-use efficiency by increasing the bushels per acre for each unit of nutrient applied without sacrificing yield potential. This is especially true for N, the major nutrient removed from the soil by most of our annual grain crops and perennial forages. Efficient fertilizer management means paying close attention to the "Four Rights" of fertilizer application. These four general management practices foster the effective and responsible use of fertilizer nutrients. These are:

1) Apply the "**Right Rate**" of fertilizer to match nutrient supply with crop requirements;
2) Apply fertilizer at the "**Right Time**" so nutrients will be available when crop demand is high;
3) Apply fertilizer in the "**Right Place**" or location where the crop can access the nutrients most effectively;
4) Use the "**Right Form**" of fertilizers that are in or are easily converted over to compounds best used by the target crop.

Applying these general practices will minimize nutrient transport from off fields and maximize crop uptake and utilization. Within each of these general categories there are a number of specific practices that we could classify as a BMP.

One-pass no-till planting and fertilization conserves moisture, saves time, and reduces tractor fuel use.

1. Right Rate of Fertilizer

What rate of nutrient to apply is the most common question asked by a farmer when evaluating a soil test report, or trying to make a crop planting decision. Soil testing is the key to making a fertilizer rate

Abbreviations and notes for this article: N = nitrogen; P = phosphorus; K = potassium; S = sulfur; C = carbon.

This publication is one of a series prepared by cooperators with the staff of the International Plant Nutrition Institute (IPNI). It is part of a project in cooperation with the Foundation for Agronomic Research (FAR) toward fulfilling the goals of a 3-year Conservation Innovation Grant (CIG 68-3A75-5-166) from the USDA-Natural Resources Conservation Service to identify fertilizer best management practices (BMPs). The intent of this publication is to help develop the BMP definition process in such a way that environmental objectives are met without sacrificing current or future production or profit potential and in full consideration of the newer technologies relevant to fertilizer use. The concept of applying the right fertilizer at the "right rate, right time, and right place" is a guiding theme in this series. For additional information, visit the websites: www.farmresearch.com/CIG and www.ipni.net.
Item # 30-3230

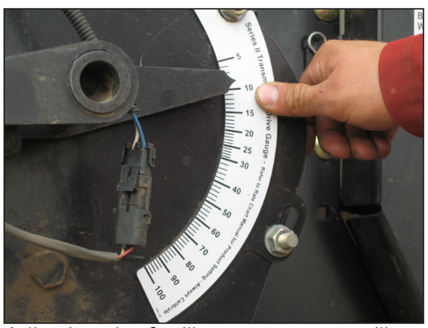
Fertilizer Best Management Practices
funded by USDA NRCS Conservation Innovation Grant

IPNI

FAR
INTO THE FUTURE
FOUNDATION FOR AGRONOMIC RESEARCH

decision on a specific field. The soil test result makes an estimate of soil nutrient supply capability, and balances that against a yield potential estimate for the field. In some cases, the soil test also uses a database of crop response trial results from an agro climatic region similar to the one where you live. This database provides an average response to nutrient addition based on the local weather and soil conditions. In the absence of this database, the soil testing company may provide a nutrient recommendation rate based on the crop nutrient requirements to meet your yield potential estimate, less the estimated nutrient supply from your soil analysis.

Selecting the exact right nutrient application rate is not always possible and in fact in semiarid regions many people feel that it is almost impossible. Weather conditions vary to the extent that the final yield is largely influenced by the amount and timing of precipitation, in combination with the management inputs used. As a result, while you can guarantee a poor crop with poor management, it is difficult to assure a good crop when good management is used. Grower experience with the yield potential of a particular field, precipitation probabilities for the area, stored soil water at seeding, management inputs like fertilizer addition, the level of production risk that the grower can tolerate, and growing season precipitation ultimately impact on the outcome each year. Together these factors make selecting the best N rate a major challenge for many farmers. Farmers should seek advice from an agronomist with these decisions to help in evaluating all their options.


Adjusting the fertilizer rate on a no-till planter.

This involves using all the available information to establish the soil nutrient status and crop requirements prior to making fertilizer application decisions. Specific BMPs include soil testing, plant analysis, setting realistic yield goals, balancing nutrient inputs with crop removal at optimum soil test levels, site-specific nutrient management, and considering crop rotation effects on nutrient needs.

a) Soil Testing

Soil testing is the main science-based tool we have to make estimates of soil nutrient supply on agricultural lands. The soil testing process is based on soil samples being taken from representative areas in a field, analyzed using a chemical extraction appropriate for the soils in the region, and either correlated with plant nutrient uptake or calibrated with crop yield (Karamanos, 2003). Resulting fertilizer recommendations would be based on how a particular crop responded to a nutrient, using the average response from a multi-year and multi-site data set. Given that a number of non-fertility factors impact final crop yield (environmental conditions, pests, etc.) it is important to remember that fertilizer recommendations based on correlation with a field response database may account for only 50% of the yield variation in the field. It is for this reason that fertilizer recommendations are often made based on yield potential, a reflection of soil water at seeding and past management conditions for a specific field (Jackson, 1998; 2000).

Periodic soil testing of all the fields on a farm acts as an excellent gauge of nutrient sustainability for crop production. These soil test results become part of a record keeping system, including prior soil test data, fertilizer and manure applications, and crop nutrient removal. Together this information acts as an indicator of whether soil fertility is increasing, decreasing, or remaining constant, and leads to responsible nutrient management decisions. If nutrient levels in a soil are allowed to decline to the point of limiting yield potential, substantial economic losses and losses in inherent soil fertility can be expected. Depletion of reserve soil fertility takes years of restoration with fertilizer and/or manure to regain optimum productivity (Roberts, 1991).


Fall soil testing after corn harvest.

Soil sample collection and handling is a critical part of getting the results you need to make accurate nutrient recommendations. Selecting the right time to collect a soil sample, accurately recording soil core depth, avoiding contamination of samples in the field and keeping samples cool prior to drying are critical practices that the farmer or agronomist control. No-till fields should also get special treatment given the stratification of P and pH in the surface 2 in. which is commonly observed. Separating the 0 to 2 in. depth from the 2 to 6 in. depth will help direct fertilizer P application depth, as well as influence herbicide choices by the farmer (Franzen, 2003).

Collecting at least 20 sample cores at random from a field is the most common method of sampling in the northern Great Plains. However, random sampling requires some bias on the part of the farmer to avoid those problem areas of the field which are not fully representative of the field average. In fact, many growers now collect 2 to 3 soil sample sets from each field to properly represent the variability which exists because of landscape position or historic activities carried out in the field (Franzen and Cihacek, 1998). This zone approach...or directed sampling approach...not only allows growers to increase the precision of their soil nutrient assessment, but also lays the ground work for future variable rate nutrient application. Variable rate nutrient application allows the grower to overcome some of the over-application and under-application of fertilizer which commonly occurs on fields with a high degree of variability. This in turn should lead to improvements in crop yield, and fertilizer use efficiency.

b) Plant Analysis

The term plant analysis refers to the total or quantitative analysis of nutrients in plant tissue. Unlike tissue testing, a qualitative measure of nutrient content, plant analysis works in combination with soil sampling to evaluate soil fertility and overall nutrient availability in problem areas of fields. Plant analysis is used in-crop to help evaluate nutrient deficiencies and take corrective action on the current crop or future crops. However, collecting samples from both 'poor' and 'good' areas of a field growing the same crop can be a useful means of establishing the role of a deficient nutrient in crop production only when soil samples are also taken from the same area. While a range of nutrient concentrations are often provided to help guide the plant analysis process, concentrations can vary with crop, variety, plant part sampled, growth stage when sampled, environment, geographic area, and other factors. All of these variables often make interpretation of plant analysis information very difficult, and limit their use to separating dramatic differences between areas of a field with markedly different production.

c) Setting a Realistic Yield Potential

A realistic yield potential is one developed from past performance in a field and use of the most current information on those factors which influence yield. In semiarid agriculture, water is the major driving variable in crop yield. More water is required to support higher yields, and more water generally helps to increase soil nutrient release to support the increased production. Nutrients also play an important role in improving the use of water by crops by increasing the amount of yield per unit of water used (Zentner et al., 2002). As a result, a field specific yield potential is best described as the highest yield obtained in a specific field, based on available soil moisture at seeding, precipitation probabilities for the region, crop water use and soil residual nutrient levels.

Setting a yield potential for a field which exceeds past production highs is often a challenge in semiarid regions. Supporting such an increase in yield potential requires a significant investment in crop production inputs, including fertilizer, which may not result in economic returns to the farmer. The production risk in semiarid regions is high given the uncertainty in growing season precipitation

d) Nutrient Uptake

Nutrient uptake by crops is often used by farmers and their agronomists to evaluate the removal of nutrients after a production year. The nutrient uptake can usually be divided into two components, total uptake and nutrient removal. Nutrient removal is the nutrient content of the harvested portion. Unlike straw left in the field, these nutrients are removed from the production system, not recycled for future crop use. Crop nutrient uptake and removal have been measured in a number of instances and estimates established for various crops (**Table 1**).

There are a number of situations where crop advisers and farmers find that they can make fairly good estimates of crop nutrient requirements based on what was grown and what was applied in a specific field. Information such as crop yield, grain protein concentration and straw management can all be used to establish the status of a nutrient such as N. For P and K the year-to-year variation in plant-available supply is minor, and annual application based on a balance between soil test levels and crop requirements can avoid depletion or over application. In no way is the determination of a balanced nutrient budget an appropriate replacement for soil testing, given the absolute need to use soil testing to establish a nutrient supply starting point. Often this type of input compared to removal assessment is carried out in the years between which comprehensive soil sampling is conducted.

It is also important to apply plant nutrients in a balanced way so that crop plants have an adequate and yet not excessive supply of all required nutrients. For example crops will better utilize N fertilizer applications if adequate supplies of P are also applied. In **Figure 1**, research results from Kansas have shown that N fertilizer is utilized more

Table 1. *Crop nutrient and removal of selected crops.*

Crop		N	P_2O_5	K_2O	S
Spring wheat, lb/bu	Uptake	1.9-2.3	.73-.88	1.6-2.0	.20-.25
	Removal	1.4-1.7	.53-.65	.40-.48	.10-.13
Winter wheat, lb/bu	Uptake	1.2-1.5	.54-.68	1.3-1.6	.18-.22
	Removal	.94-1.1	.46-.56	.30-.38	.12-.16
Barley, lb/bu	Uptake	1.3-1.5	.50-.61	1.2-1.5	.15-.18
	Removal	.88-1.0	.38-.46	.29-.35	.08-.10
Corn, lb/bu	Uptake	1.4-1.7	.57-.69	1.2-1.4	.13-.16
	Removal	.87-1.1	.39-.48	.25-.30	.06-.07
Canola, lb/100 lb	Uptake	5.7-7.1	2.6-3.3	4.2-5.1	.97-1.2
	Removal	3.5-4.2	1.9-2.3	.92-1.1	.57-.69
Sunflower, lb/100 lb	Uptake	3.4-4.1	1.2-1.4	1.7-2.2	.40-.45
	Removal	2.4-3.0	.70-.90	.55-.65	.20-.25
Peas, lb/bu	Uptake	2.8-3.4	.76-.92	2.5-3.0	.22-.28
	Removal	2.1-2.6	.62-.76	.64-.78	.12-.14
Lentils, lb/bu	Uptake	2.7-3.4	.73-.90	2.3-2.8	.27-.33
	Removal	1.8-2.2	.57-.67	.97-1.2	.13-.17
Alfalfa, lb/ton	Removal	52-64	12-15	54-66	5.4-6.6
Grass hay, lb/ton	Removal	31-38	9-11	39-48	3.7-4.7

Canadian Fertilizer Institute, 2001.

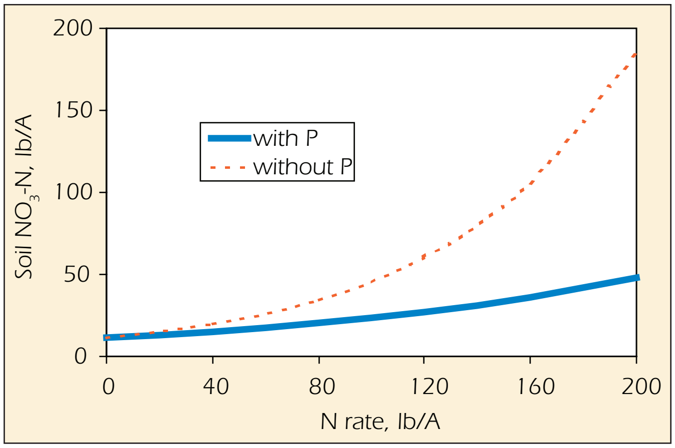


Figure 1. Effect of N and P fertilization on residual NO_3-N in the upper 10 ft. after 30 years of irrigated corn production (Kansas, Schlegel).

efficiently by crops when P fertilizer is added. Without P additions more N was not used by crops as indicated by increased levels of residual nitrate (NO_3^-) N within the top 10 ft. of soil sampled.

e) Site-Specific Nutrient Management

Fertilizing soils rather than fields is an emerging BMP that continues to gain in popularity with technology development. Using some form of field diagnostic, such as intensive soil sampling, soil and crop remote sensing, yield mapping, or scouting records, whole fields are divided into management units where the fertilizer application used is independent of the rest of the field. This form of site-specific fertility management assures that nutrient needs are properly identified and appropriate corrective fertilizer applications are made only where required. For example, a field divided into knolls, mid-slope and depressions areas may have no N demand in the depressions, a moderate rate on the mid-slope and high rate recommendation on the knoll. However, the farmer knows that while the fertility level is low on the knoll, so is the water supply and yield potential. Field history can also be zoned to account for old yard sites, past manure management and sections of the field which may have been broken from natural grassland later than other areas (Franzen and Cihacek, 1998). Together, this information can be used to develop zone specific nutrient application strategies. This management practice can take into account the natural variation in soil fertility and nutrient supply.

Optical plant sensors have also been developed that use the crop color as an indication of N sufficiency. These sensors use a reference color for the specific crop to assess the need for added N at a specific growth stage. The sensor is mounted on a field applicator capable of varying the N rate on-the-go. This technology uses the plant as an indicator of N sufficiency, integrating the variety with soil and fertilizer N supply. In instances where field variability of N is large, this type of application prevents the over-application characteristic of fixed field rates in those areas where the soil N supply is sufficient.

f) Managing Nutrients with Rotational Diversity

Crop diversity is the key to economic and agronomic success in semiarid regions, especially when extended crop rotations are coupled with no-till seeding systems. Including both oilseed and grain legume crops in rotation with cereals has been shown to improve yields and economic returns to farmers (Zentner et al., 2002). Grain legumes are of particular interest related to crop nutrients given their ability to fix all, or a portion, of their N requirements. Not only do they fix the N they need to grow a crop, but they help contribute to the N supply for subsequent crops in rotation. Currently, the NDSU Extension Service recommends a 40 lb N/A credit when grain legumes are grown, while commercial labs give credits that are either a similar fixed rate, or in some way related to the grain legume crop yield. These savings in crop N requirements can have a major impact on the profitability of both the grain legume crop and subsequent crops in rotation.

2. Right Timing

The demand for a nutrient by a growing crop is not constant through the growing season, with the highest uptake associated with the period of most rapid growth. Timing fertilizer applications so that they provide a plant-available supply of nutrients when the crop needs them is the desired goal. Plants subject to a deficiency during a high demand period of growth may not recover to achieve full yield potential. An example of this is the impact of an early season P deficiency on wheat, where an absence of adequate P during the first 4 to 6 weeks of growth limited tiller and root formation by the crop (**Table 2**). Even when the P deficiency was corrected after 4 to 6 weeks, the negative impact on the crop had already occurred, illustrating the critical early season response.

Table 2. Impact of P deficiency during a 10-week growth period on the development of tillers and secondary (tiller) roots of wheat.

Weeks without P in 10-week growth period	Tillers/6 plants at week 10	Secondary roots/ 6 plants at week 10
Control – no deficiency	27.7	120.0
First 2 weeks	22.3	76.2
First 4 weeks	10.3	21.6
First 6 weeks	9.4	19.8

Adapted from Boatwright and Viets, 1966.

Where fertilizers are subject to transformation in the soil, application timing can play a critical role in optimizing crop nutrient response. Nitrogen is likely the nutrient which is influenced most by the soil moisture and temperature conditions which demands management attention. A project on heavy clay soils in Manitoba found that fall N application timing had less of an impact on crop yield response in upland landscape positions than lowland areas (**Table 3**). Even though all of the urea N treatments were banded in this study, delaying the N application timing improved the crop response with the wetter soil conditions in the lowland areas of the field.

Table 3. Effect of landscape position on wheat grain yield response to time of N band application in Manitoba.

	Upland area, 33 lb N/A[1]	Lowland area, 28 lb N/A
	Grain yield, bu/A	
Early fall (mid-Sept)	37.9 a[2]	29.1 c
Mid fall (early Oct)	38.0 a	28.7 c
Late fall (Mid-Oct)	37.2 a	32.4 ab
Spring (at seeding)	36.7 a	32.5 a
Early fall + inhibitors	36.7 a	29.4 bc
Check (no N)	28.8 b	18.5 d

Tiessen et al., 2003.
[1] *Value in parentheses represents the average soil residual NO_3-N to 12 in. depth at the four trial locations.*
[2] *Yields followed by the same letter within columns are not significantly different.*

3. Right Placement

An important part of optimizing crop response to a fertilizer nutrient is ensuring that the nutrient is placed in a location where crop root interception or dissolved nutrient movement to roots is in time for optimum growth. Maximizing crop uptake also reduces the potential for losses of nutrients. The mobility of a nutrient in the soil plays the biggest role in how important placement is. For example, low mobility of P in calcareous soils means that short-term crop utilization of the P is improved considerably when it is placed close to the germinating seed. When broadcast applied on low P soils, optimum P rates are generally twice that which is required when seed placed or side banded, and incorporation with tillage is sometimes required to improve exposure to plant roots.

Placement can be a powerful management tool to minimize N losses. Under ideal conditions, the goal is to apply the N so that it is in a plant-available form and in close proximity to plant roots. Banding of fertilizer N is a very important BMP widely used on the northern Great Plains with no-till production systems. It has been shown to reduce per-unit production costs by increasing fertilizer efficiency (Harapiak et al., 1986). Seeding system also plays an important role on the impact of fertilizer placement. When incorporated with tillage, barley showed a similar response to broadcast and in-soil band application (**Table 4**). However, when the broadcast urea is applied onto the residue covered surface of a no-till field and not incorporated, grain yield was reduced by 31% relative to an in-soil band. When incorporation is not an option with surface applied fertilizer N (i.e. in perennial forage crops) timing of the application of urea to avoid warm and wet conditions, can help minimize N losses.

Nitrogen is precision-banded to the side of the seed-row using a coulter-opener.

Table 4. Barley yield response to tillage and fertilizer urea placement.

	Conventional tillage	No-till
	Grain yield, bu/A	
Broadcast - 65 lb N/A	62	45
Band – 65 lb N/A	64	65

Malhi and Nyborg, 1992.

Seed-row placement of fertilizer is a common practice, and a very efficient means of applying nutrients to a crop. However, the use of seed-row fertilizer is limited to the crop grown, fertilizer used, the seeder row spacing, and seed/fertilizer distribution or spread laterally in the soil. Seeding a sensitive crop like canola on a wide row spacing with little seed/fertilizer spread will severely limit the amount of fertilizer which can be seed placed. Farmers who want to increase their seed placed N application are recommended to increase their seed/fertilizer spread. For example, a 2 in. spread on a 12 in. row spacing drill is limited to 20 to 27 lb urea N/A, while an 8 in. spread on the same drill can tolerate 56 to 71 lb urea N/A. Further information on seed-row fertilizer application is available in NDSU Extension Bulletin EB-62 (Deibert, 1994)

The demand for time to get fertilizers applied to fields after harvest, but before seeding, often results in some fertilizer being applied onto snow-covered fields. This practice is not recommended at all for P fertilizers, given the high probability that melting snow will remove some of the surface soil in runoff, and in turn the applied P. Urea N fertilizer application onto snow-covered fields requires that the soil below the snow is thawed so that the dissolved urea-water solution infiltrates the soil. Soils which are frozen are not suited to urea application on the snow as the chance of runoff is much higher. Research in North Dakota has shown that when compared to fall or spring application with incorporation, urea application on frozen soils can result in large yield and grain protein losses (**Table 5**). The critical issue appears to be avoiding soils which are frozen, and only considering the practice where you have thawed soils

Table 5. Application of urea to frozen soils preceding spring wheat, Carrington, ND.

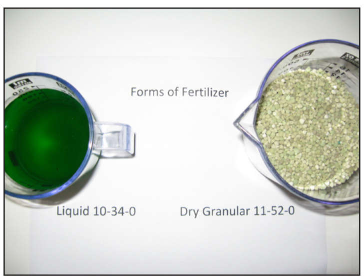
Application Timing	Yield, bu/A	Protein, %
Fall surface applied, incorporated	45.4	14.5
Soil frosted, not deeply frozen	45.8	13.8
Soil deeply frozen, December	27.6	12.7
Soil deeply frozen, March	33.3	13.0
Prior to seeding, incorporated	49.6	14.6
LSD 5%	5.0	0.5

Endres, Schatz and Franzen, 1996. Franzen, 2003.

and a high probability of snow melt within a week's time.

4. Right Fertilizer Form

Plants take up the bulk of their nutrients from the soil in forms which are best suited to their use in the crop. Nitrogen is taken up as NO_3^- and ammonium (NH_4^+), P as primary ($H_2PO_4^-$) or secondary (HPO_4^{2-}) orthophosphate, K in its elemental ion form (K^+) and S as sulfate (SO_4^{2-}). Fertilizers are formulated to be either in these plant-available forms, or converted over to these forms after application to the soil. In some instances this conversion limits immediate use by the plant, requiring specific application management for efficient use. An example of this is elemental sulfur which must first be converted to sulfate to be plant-available, a process that requires surface application of the fertilizer and 6 to 12 months for the conversion to be completed. In other instances, a fertilizer form may be selected to delay conversion to a plant-available form, minimizing potential losses from the soil. An example of this would be fall applied N in the NH_4^+ form, which in cool soils is slow to convert to the NO_3^- form where it is subject to potential losses by leaching in coarse textured soils, or denitrification in saturated soils.



Two different forms of P fertilizer.

Recent research has brought a few new products to the fertilizer market which changes the rate of nutrient release, mainly for N fertilizers. A urease enzyme inhibitor can be applied to urea based fertilizers to reduce the potential for gaseous loss (volatilization) when urea is hydrolyzed releasing ammonia (NH_3). This delay in NH_3 release is most beneficial when the urea is surface broadcast because urea being very water soluble has a better chance to move into the topsoil with adequate moisture from a precipitation or irrigation event. Once the urea is in the soil volatilization losses are minimal. The urease inhibiting effect is reported to last 10 to 14 days at the recommended rate of urease inhibitor application. Fertilizer urea has also been developed with polymer coatings to slow the release of urea-N from the fertilizer granule. The movement of dissolved urea through the polymer membrane is controlled by soil moisture content and temperature, which in turn influences the rate of N release. Some polymers are developed to release N uniformly over an entire growing season for use on golf course turf, while others are developed to release more rapidly to be available for uptake by annual crops (30 to 60 days).

5. Other Related Beneficial Management Practices

a) Minimizing Nutrient Transport Off Fields

From an environmental impact perspective the goal of land managers should be to retain soil and associated nutrients within the boundaries of a field and the rooting zone of the crops grown. Management practices that reduce soil erosion by surface water flow, and or wind erosion help keep applied nutrients attached to soil particles in the crop rooting zone from leaving fields. Fertilizer application based on soil testing and realistic yield goals helps to ensure that proper rates are recommended and applied. This improves plant nutrient use efficiency, and lessens the potential for residual nutrients to accumulate to excessive levels in a field and pose an environmental threat.

b) Nutrient Losses Minimal in Semiarid Regions

Retention of soluble nutrients in the rooting zone of crops ensures efficient recovery and effective use in food production systems. Leaching occurs when excessive residual mobile nutrients like NO_3-N are left in the soil profile and moved below the rooting zone (48 in.) by precipitation. While leaching is not a common problem in most semiarid regions, historic use of fallow has been shown to leave NO_3-N accumulated below the rooting zone of crops. Water is also the driving variable behind N losses to the atmosphere by denitrification, the gaseous loss of NO_3-N under saturated soil conditions. Soils which have warmed enough to stimulate microorganism activity, but are oxygen limited due to excess water, can see N losses by denitrification as the microbes use oxygen from NO_3^- and result in volatile N emissions. However, soils that are well drained and normally do not become saturated in the spring are not prone to N losses by denitrification. In the absence of leaching and denitrification, the soils in semiarid areas are effective in retaining residual soil NO_3-N for crop use. Soil testing can play a major role in monitoring these soil nutrient levels, allowing them to be effectively accounted for in crop nutrient budgets.

c) Conservation Tillage, Soil Erosion, and Carbon Sequestration

Farmers on the Northern Great Plains are leaders in North America for conservation tillage practices with the adoption of no-till seeding systems. The retention of crop residues on the soil surface has significantly reduced the loss of soil by wind and water erosion, while at the same time improving moisture conservation and crop yields. When fertilized according to soil test recommended rates, increased crop yields lead to higher levels of crop residues returned to the surface of no-till fields for erosion protection.

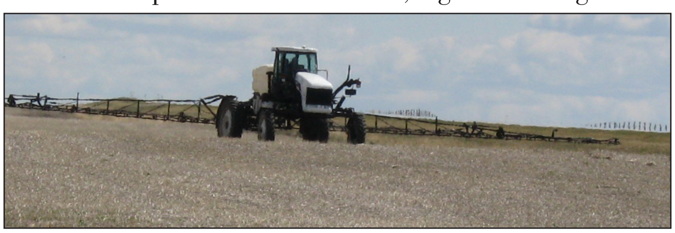
Crops grown with proper nutrition are also playing a major role in building soil organic matter. Increased crop residue production leads to increased residue incorporation to build soil organic matter levels. In long-term rotation studies across the semiarid region of western Canada, moderate applications of N and P fertilizer have been shown to increase surface soil organic matter content (**Table 6**). In these studies fertilizer N application not only increased the quantity of organic matter, but also improved the supply

Table 6. Influence of fertilization on the average organic C and total N concentration in surface soils from long-term continuous wheat rotations on the Canadian Prairies.

Location	Fertilizer	Organic C	Total N
		%	%
Swift Current (Brown soils)	P	1.78	0.197
	N + P	2.15	0.226
Lethbridge (Dark Brown soils)	None	1.62	0.149
	N + P	1.88	0.171
Indian Head (Black soils)	None	2.48	0.198
	N + P	2.59	0.223

Biederbeck et al., 1984; Janzen, 1987; Campbell et al., 1990.

of organic N and the ability of the soil to replace plant available N (Biederbeck et al., 1984; Janzen, 1987; Campbell et al., 1990). The positive effects of fertilization can be directly attributed to the amount of crop residues returned to the soil. The application of fertilizer increases grain yields, and straw and root production, both of which support the formation of soil organic matter. This increase in soil organic matter also represents an increase in soil C storage, or sequestration. By reducing tillage the rate of soil C decomposition is decreased, and a new increased equilibrium level of soil C is achieved. This sequestration of atmospheric C as stable soil organic matter has been shown to be one of the few means of producing a net reduction in atmospheric carbon dioxide, a greenhouse gas.



Preplant application of glyphosate herbicide in a no-till system.

d) Risk Management Considerations in Semiarid Agriculture

Managing production risk is a big part of success in semiarid agriculture. Those farmers who have evaluated all the manageable risk factors, and taken some action to address these, can often show positive results for their efforts. There are many aspects to consider as part of risk management.

- Maximize water for your crops. Saving water, whether it is snow or rain, where it falls in a field is critical to optimizing crop yields in semiarid regions. Using reduced, or no-till practices, are effective ways to conserve water by standing stubble to trap snow in place and residues in general to improve water infiltration and reduce losses from surface runoff.
- Carefully assess soil water levels in the spring prior to seeding to formulate a plan for nutrient management based on crop yield potential. Precipitation comes with a certain level of risk each year, but stored soil water in the spring is an established resource which a farmer can bank on.
- Select crops based on their water use characteristics. Grain legumes generally use surface water and have a short water use period. Cereals and oilseeds use water deeper in the soil profile, and for a longer period of time. Balancing the crops grown with the soil water situation can help in optimizing grain yields.

Lentil crop seeded no-till into wheat residue.

6. Taking Stock of Your Fertilizer Management

It is now time to take stock of how you measure up in the use of fertilizer BMPs. Using the reference chart (**Appendix 1**), evaluate the number of categories under which you rank in the top two categories. If you cannot demonstrate a suitable fit in these two top categories, you may want to re-evaluate some of your current management practices. ■

Author Information

Dr. Jensen is IPNI Northern Great Plains Region Director, located at Saskatoon, Saskatchewan; e-mail: tjensen@ipni.net. Dr. Johnston is IPNI Vice President, Asia and Oceania Group, Saskatchewan. Dr. Franzen is with North Dakota State University Cooperative Extension. Mr. Stika is with USDA-NRCS at Dickinson, North Dakota.

References

Biederbeck, V.O., C.A. Campbell, and R.P. Zentner. 1984. Effect of crop rotation and fertilization on some biological properties of a loam in southwestern Saskatchewan. Can. J. Soil Sci. 64: 355-367.

Boatwright, G.O. and F.G. Viets, Jr. 1966. Phosphorus absorption during various growth stages of spring wheat and intermediate wheatgrass. Agron. J. 58: 185-188.

Campbell, C.A., R.P. Zentner, H.H. Janzen, and K.E. Bowren. 1990. Crop rotation studies on the Canadian prairies. Research Branch, Agriculture and Agrifood Canada, Publication 1841/E.

Campbell, C.A., R.P. Zentner, F. Selles, and O.O. Akinremi. 1993. Nitrate leaching as influenced by fertilization in the Brown soil zone. Can. J. Soil Sci. 73: 387-397.

Canadian Grains Council. 1993. Risk management guide for wheat production. Pp. 30. Canadian Grains Council. Winnipeg, MB.

Deibert, E.J. 1994. Fertilizer application with small grain seed at planting. NDSU Extension Service, Publication EB-62.

Franzen, D.W. 2003. North Dakota soil and fertilizer handbook. NDSU Extension Service, North Dakota State University, Fargo, ND.

Franzen, D.W. and L.J. Cihacek. 1998. Soil sampling as a basis for fertilization application. NDSU Extension Service, Publication SF-990.

Grant, C.A., E.H. STobbe, and G.J. Racz. 1985. The effect of fall-applied N and P fertilizer and time of N application on yield and protein content of winter wheat grown on zero-tilled land in Manitoba. Can. J. Soil Sci. 65: 621-628.

Harapiak, J.T., R.M.N. Kucey, and D. Flaten. 1996. Nitrogen sources and placement in wheat production. In Wheat production in Canada – A Review. Proceedings of the Canadian Wheat Production Symposium. March 3-5, 1986, Saskatoon, SK.

Jackson, G.D. 1998. Predicting Spring Wheat Yield and Protein Response to Nitrogen. Montana State University Fertilizer Facts No. 17. Feb. 1998. [Online] [3 p.] Available at: http://landresources.montana.edu/FertilizerFacts/ (accessed 21 Apr, 2004).

Jackson, G.D. 2000. Nitrogen Fertilization of Dryland Malt Barley for Yield and Quality. Montana State University Fertilizer Facts No. 24. Dec. 2000. [Online] [3 p.] Available at: http://landresources.montana.edu/FertilizerFacts/ (accessed 21 Apr, 2004).

(continued on p. 8)

Appendix 1. BMPs for Fertilizer Management.

Practice	Best Practice	Making progress	Improvements Required
"Right Rate" Diagnostics and Considerations			
Soil testing	Annually test for N where it is applied. No less than every 3 years for P and K.	Less than one-fourth to one-third of fields tested each year.	Never test or last soil test was more than 10 years old.
Plant tissues analysis	Routinely use tissue sampling to evaluate effectiveness of fertility program.	Occasionally use tissue sampling for diagnostic purposes.	No tissue samples collected.
Yield potential	Develop crop and field specific yield potentials based on measured yield history and crop sequence.	Develop yield potentials for each crop on the farm, regardless of field.	Yield potentials not considered in planning, or arbitrary or unrealistic yield potentials are used.
Nutrient uptake	Soil test annually, record crop yields, analyze grain for nutrient content and account for nutrient use.	Nutrient rates are modified between soil testing years in consideration of nutrient removal.	No consideration of soil testing or nutrient removal.
Site specific management	Evaluating field variation when making fertilizer application decisions.	Fields are grouped based on the dominant soil-landscape formation.	No consideration to field variability in fertilizer application
Crop rotation benefits	Fertilizer rates are modified based on the previous crop.	Some N fertilizer rates are modified when considering the previous crop.	Same fertilizer rates used with no consideration to make modifications because of the previous crop type.
"Right Form" Choices			
Consider and choose optimum fertilizer forms	Consider N and other nutrient forms when selecting fertilizer types and application timing.	Incorporate broadcast urea or UAN within 24 hours	Unaware of any form effects. Surface broadcast urea or UAN with no incorporation. Concerned only with applying the nutrient regardless of form.
Balanced fertilizer blends	Meet the specific needs of other nutrients when N rates are set.	Fertilizers applied as a fixed blend based on N needs.	N rates set with no consideration to other nutrient needs.
"Right Placement" Decisions			
Location relative to soil surface	Use subsurface placement of most N, and place at least some of the less mobile nutrients near seed.	Broadcast and incorporate all fertilizer throughout surface soil.	Broadcast application with delayed or lack of incorporation.
Conservation tillage	Plant using a low disturbance one or two pass no-till (direct seeding) system.	Minimum tillage used to maintain reasonable (30%) residue cover.	Conventional tillage with the majority of the residue buried or burned.
"Right Timing" Determinations			
	Consider soil texture, time of crop uptake and plant source availability when considering time of fertilizer applications.	Apply all N at or immediately before seeding.	All nutrients, regardless of soil texture, applied well in advance of seeding.

References...from p. 7

Janzen, H.H. 1987. Effect of fertilizer on soil productivity in long-term spring wheat rotations. Can. J. Soil Sci. 67: 165-174.

Johnston, A.M. and H.H. Janzen. 1992. Influence of crop rotation and nutrient amendment on soil quality and subsoil nitrates of a Dark Brown Chernozem. Pp. 119-124. *In* Proceedings 29th Alberta Soil Science Workshop, Lethbridge, AB.

Karamanos, R.E. 2003. Soil testing – the art of the science. pp. 11-16. In Proceedings of the Western Canada Agronomy Workshop. Canadian Fertilizer Institute, Ottawa, ON.

Malhi, S.S. and M. Nyborg. 1992. Placement of urea fertilizer under zero and conventional tillage for barley. Soil Tillage Res. 23: 193-197.

Roberts, T.L. 1991. Best management practices (BMPs) and sustainable agriculture. pp. 10-28. *In* 1991 Alberta Soil Science Workshop. Faculty of Extension, University of Alberta, Edmonton, AB.

Schlegel, A.J., K.C. Dhuyvetter, and J.L. Havlin. 1996. Economic and environmental impacts of long-term nitrogen and phosphorus fertilization. J. Prod. Agric. 9: 114-118.

Tiessen, K.H.D., D.N. Flaten, C.A. Grant, R.E. Karamanos, D.L. Burton, and M.H. Entz. 2003. Efficiency of fall-banded nitrogen fertilizer in Manitoba: Influence of application date, landscape position and fertilizer additives. pp. 1-12. *In* Saskatchewan Soils and Crops Workshop proceedings. University of Saskatchewan, Saskatoon, SK.

Zentner, R.P., D.D. Wall, C.N. Nagy, E.G. Smith, D.L. Young, P.R. Miller, C.A. Campbell, B.G. McConkey, S.A. Brandt, G.P. Lafond, A.M. Johnston, and D.A. Derksen. 2002. Economics of Crop Diversification and Soil Tillage Opportunities in the Canadian Prairies. Agron. J. 94: 216-230.