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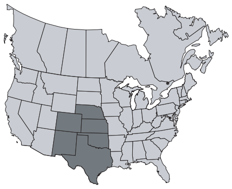
Best Management Practices for Fertilizer



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This publication is one of a series on fertilizer best management practices (BMPs), prepared by regional directors of the Potash & Phosphate Institute (PPI)/Potash & Phosphate Institute of Canada (PPIC). This effort is in cooperation with the Foundation for Agronomic Research (FAR) toward fulfilling the goals of a 3-year Conservation Innovation Grant (68-3A75-5-166) from the USDA-Natural Resources Conservation Service (NRCS). The intent of these publications 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.

Conserving Resources and Building Productivity… A Case for Fertilizer BMPs in the Great Plains

BEST management practices (BMPs) are a hot topic these days. Most of the interest in BMPs for agriculture is driven by the increasing awareness that how we manage our soils and landscapes can have a big impact on the environment at large. As sincere and competent stewards of the land, farmers in the Great Plains have implemented soil conservation practices that rival any other resource conservation activity in the world. The resulting reduction in soil erosion by wind and water…along with moisture conservation practices…have improved soils while increasing crop yields and improving whole-farm economics.

Fertilizer nutrients are essential in meeting the crop yield and quality goals of modern agriculture. With reduced tillage systems, many semiarid regions have been able to intensify cropping, thus reducing the use of fallow for soil moisture accumulation, and increasing the need to replace the nutrients removed by the increased cropping intensity. How we handle fertilizer inputs (e.g., rate, timing, and placement) provides the foundation for fertilizer BMPs and the potential for maximum positive economic returns from fertilizer use.

The Dust Bowl of the 1930s in the U.S. was a lesson to the world concerning the importance of conserving natural resources. That is one of the goals of BMPs.

BMPs focus on intensive management, improved efficiency, site-specific recommendations, 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, crop, and management expertise. Ultimately, it comes down to past research, farmer and associated consultant experience, and the knowledge of the local soil and climatic conditions that dictate the success of a particular BMP in a specific field.

There are three general management practices that foster the effective and responsible use of fertilizer nutrients:

- Matching nutrient supply with crop requirements;
- Fertilizer application (e.g., rate, timing, placement);
- Minimizing nutrient transport off fields.

Within each of these general categories, there are a number of specific practices that we can classify as BMPs.

1. Matching Nutrient Supply with Crop Requirements

This involves using all available information to establish the soil nutrient status and crop requirements prior to making fertilizer application decisions. Specific BMPs include soil testing, plant analyses, setting realistic yield

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goals, and balancing nutrient inputs with crop removal at optimum soil test levels.

a) Soil Testing

The main science-based tool we have to estimate a soil's capacity to supply nutrients on agricultural land is soil testing. The soil testing process is based on soil samples being taken from representative areas in a field, analyzed using an appropriate chemical extraction method, and either correlated with plant nutrient uptake or calibrated with crop yield response. Resulting fertilizer recommendations are 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 soil testing is not an exact science and that resulting fertilizer recommendations are not absolute. In other words, absolute availabilities cannot be evaluated (Black, 1993). Good examples of this are demonstrated in Gordon (2005) and Ortega et al. (1997). Nevertheless, soil testing remains one of the most valuable and effective nutrient management tools available.

Periodic soil testing acts as an excellent gauge of nutrient sustainability for crop production. Soil test results can 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 declines in soil fertility can be expected. This was shown clearly with P in a long-term corn-soybean study in Kansas (Gordon, 2003).

Figure 1 shows that annual application of 30 lb P_2O_5/A over 42 years maintained soil test P at near the initial (1960) level until about 1985. Since then, soil P levels have declined. Corn grain yields were 11% greater for the period 1985-2002 than for 1960-1984. This indicates that the 30 lb P_2O_5/A rate was not keeping pace with the crop removal rate. Where no P fertilizer was applied soil test P declined to half of the original value.

b) Plant Analysis

The term plant analysis refers to the total or quantitative analysis of nutrients in plant tissue. Plant analysis works with soil testing to evaluate soil fertility and overall nutrient availability. Plant analysis is used in-season to help evaluate nutrient deficiencies and take corrective action on the current crop or future crops. It can be a powerful tool in adding accuracy to the monitoring process as nutrient management plans are implemented. While a range of nutrient concentrations is 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. Collecting samples from both 'poor' and 'good' areas of a field can be a useful means of improving understanding and management practices, especially when soil samples are taken from the same area.

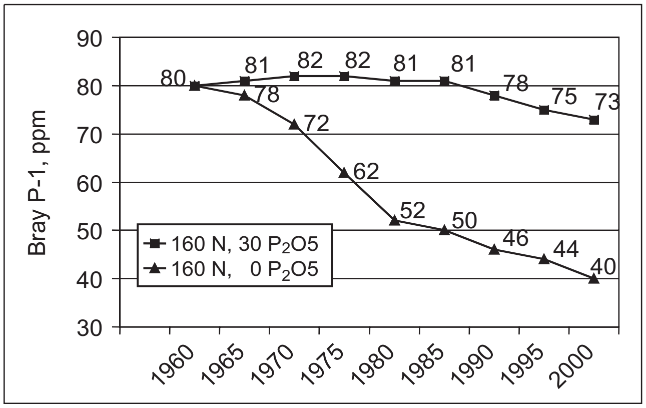

Figure 1. Neglecting soil fertility severely depleted reserves of soil P in a long-term corn-soybean rotation study (Kansas, Gordon, 2003).

c) Establishing Realistic Yield Goals

Suggested recommended application rates are often tied to yield goals for several nutrients. Yield records should be used to set individual realistic, but progressive, yield goals for each field. Appropriate yield goals for a specific field should be high enough to take advantage of high production years when they occur, but not so high as to jeopardize environmental stewardship and/or profitability when environmental conditions are not as favorable. Appropriate yield goals fall between the average yield obtained in a field over the past 3 to 5 years and the highest yield ever obtained in a particular field (Leikam et al., 2003).

In semiarid dryland agriculture, water is generally the major variable determining crop yields. It is important to note that balanced nutrition plays an important role in improving the use of water by crops by increasing the amount of yield per unit of available water (Stewart, 2001). As a result, a field-specific yield goal is sometimes determined based on available soil moisture at seeding, precipitation probabilities for the region, irrigation water, crop water use, and soil residual nutrient levels. For nitrogen (N) specifically, if yield estimates indicate a larger yield than fertilized for originally, additional N can be applied before the crop becomes too advanced.

d) Nutrient Budgets

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 phosphorus (P) and potassium (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 need to use soil testing to establish a nutrient supply starting point. Often, this type of input/removal assessment is carried out in the years between comprehensive soil sampling.

There are nutrient removal information sources available on the internet... check out the PPI website >**www.ppi-ppic.org/nutrientremoval**<.

2. Fertilizer Application

The way we handle fertilizers can have a major impact on the efficiency of nutrient use by crops and potentially impact the surrounding environment. In all instances, we strive to improve fertilizer-use efficiency by increasing production 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 annual grain crops and perennial forages. Efficient fertilizer management means paying close attention to the "Four Rights" of fertilizer application.

a) Right Rate and Balance of Nutrients

Most agronomists have heard about Liebig's Law of the Minimum, which states that the yield of a crop will be determined by the element present in most limiting quantity. In other words, the deficiency of one nutrient cannot be overcome by the excess of another. Soil testing and use of crop nutrient uptake and removal information are important rate guides to ensuring that balance among soil-available nutrients and applied fertilizer prevents nutrient deficiencies from limiting crop yields.

An example of the role of nutrient balance in optimizing production is illustrated in a high-yield irrigated corn study conducted in north central Kansas (**Table 1**). While application of N alone increased corn grain yield substantially above the no fertilizer control, it was only when other nutrients were added with N that yield was optimized. These data clearly shows the importance of balanced fertility inputs and the stepwise effect of the sequential adding of N, P, K, and S on increasing irrigated corn yield.

Table 1. Response of irrigated corn yields to application of N, P, K, and S fertilizer (Crete silt loam soil, 2003-2004). Rates of fertilization were 300 lb N/A, 100 lb P_2O_5/A, 80 lb K_2O/A, and 40 lb S/A (Kansas, Gordon, 2005).

Treatment	Grain yield	Response to inputs
	- - - - - - - - bu/A	- - - - - - - -
Unfertilized check	137	—-
N	187	50
N + P	243	106
N + P + K	256	119
N + P + K + S	265	128
LSD (p<0.05)	7	

b) Right Fertilizer Form

Plants take up the bulk of their nutrients from the soil in specific forms. Nitrogen is taken up as nitrate (NO_3^-) and ammonium (NH_4^+), P as primary ($H_2PO_4^-$) or secondary (HPO_4^{2-}) orthophosphate, K in its elemental form (K^+) and S primarily as sulfate (SO_4^{2-}). Fertilizers are formulated to be either in these plant-available forms, or easily converted 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 S, which must first be converted to sulfate to be plant-available, a process that requires up to several weeks or even months for the conversion to be completed. In other instances, a fertilizer form may be selected to delay conversion to another 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. There are also several N fertilizer products available that are specifically designed to delay N release.

c) Right Placement

An important part of optimizing crop response to a fertilizer nutrient is placing the nutrient in such a way that it provides rapid uptake by the crop, and reduces potential losses. The mobility of a nutrient in the soil is a major consideration in its placement. 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.

Placement can be a powerful management tool to minimize nutrient losses. Under ideal conditions, the goal is to apply nutrients in the plant-available form in reasonably close proximity to the plant roots. Deep banding of fertilizer N and P is often a very important BMP. This was shown in an eastern Kansas study where tillage and P placement methods were compared (**Figure 2**). Deep banding of P was especially important in reducing bioavailable P (FeO-strip method) losses in the ridge and no-till systems (Janssen et al., 1999).

Strip tillage is an increasingly popular practice in corn production in many areas of the Great Plains. Strip tillage helps overcome some of the problems associated with no-till (cool, moist early season soil conditions). It also opens up new fertilizer placement options compared to no-till. During the tillage operation, plant nutrients can be placed several inches deep, directly below the seedbed. This can be an economical and agronomically efficient way of supplying some of the crop's nutrient requirements (Kansas State University, 2004; Irrigation Research Foundation, 2006).

Seeding system also plays an important role on the impact of fertilizer placement. For example, the use of air

BMPs for Fertilizer Management in the Great Plains

Practice	Best Practice	Making Progress	Improvements Required
Diagnostic			
Soil testing	Annually test for N where it is applied. 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 more than 10 years old.
Plant tissue analysis	Routinely use tissue sampling to evaluate effectiveness of fertility program.	Occasionally use tissue sampling for diagnostic purposes.	No tissue samples collected.
Yield goals set	Develop crop- and field-specific yield goals based on measured yield history and crop sequence.	Develop yield goals for each crop on the farm, regardless of field.	No yield goals considered in planning, or arbitrary or unrealistic yield goals are used.
Nutrient budgets	Consider last year’s crop removal and this year’s yield goal, in matching fertilizer applied with current soil test results.	Consider crop nutrient removal based on a desired yield goal, or replace last year’s removal regardless of soil test level.	No consideration for crop nutrient removal or past production.
Fertilizer Application			
Right rates and balance	Meet the specific needs of all nutrients.	Fertilizers applied as a fixed blend based on N needs.	Crop N rate set with no consideration to other nutrient needs or variation among fields.
Right form	Consider N form when selecting fertilizer types and application timing.	Incorporate broadcast urea or UAN within 24 hours, unless on soils with low pH or low soil temperatures.	Unaware of any form effects. Surface broadcast urea or UAN with no incorporation in warm weather.
Right placement	Use band placement of some nutrients, and place at least some of the less mobile nutrients near seed.	Broadcast and incorporate all fertilizer throughout surface soil.	Broadcast application.
Right timing	Consider timing of crop uptake and plant source availability when considering time of application. Where possible, use fertigation to “spoon-feed” the crop N throughout the season.	Apply all N before seeding.	All nutrients applied well in advance of seeding.
Site-specific management	Evaluating field variation when making fertilizer application decisions and apply N variably based on in-field zones.	Fields are grouped based on the dominant soil-landscape formation.	No consideration to field variability in fertilizer application.
Minimizing Nutrient Losses			
Leaching avoidance on sensitive soils and landscapes	Full use of N BMPs: soil NO_3 testing, split N application, fall cover crops, groundwater monitoring.	Use of half the BMPs at left.	No consideration of potential leaching losses or use of BMPs.
Conservation tillage	Adoption of no-till or strip-till system.	Minimum tillage used to maintain reasonable (30%) residue cover.	Conventional tillage with the majority of the residue buried.
Buffer strips	Have buffer strips next to surface waters and reduce tillage near the area to minimize soil transport.	No buffer maintained, but use no-till adjacent to surface water edge.	Surface water not considered in management of fertilizers.
Irrigation management	Use center pivot, LEPA, or subsurface drip systems and base water application on local crop water use and PET monitoring stations, thus avoiding water and nutrient waste.	If using flood irrigation fields are diked so that excess water does not escape the field.	Water is applied with little regard to soil moisture or PET. Excess water containing sediments and nutrients is allowed to leave the field and run into nearby streams.

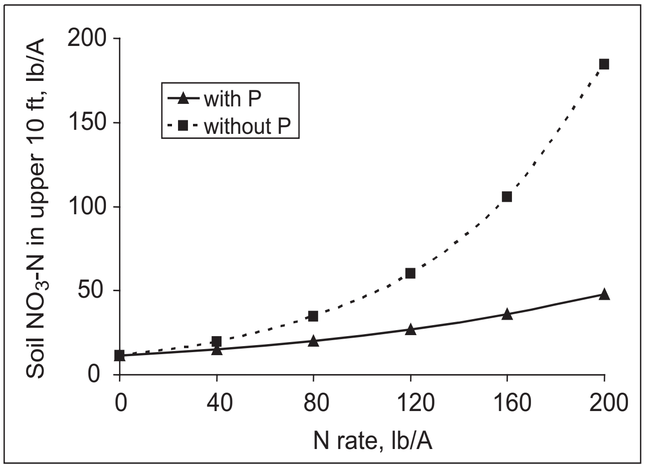

Figure 2. **Total 3-year average bioavailable P losses as influenced by tillage and P placement (Kansas, Janssen et al., 1999).**

seeders in small grain production in the Great Plains and Canadian Prairies has increased producer flexibility in placing fertilizer with the seed (Roberts and Harapiak, 1997). Also, when incorporation is not an option with surface applied fertilizer N, selecting a less volatile form such as NH_4NO_3, or timing application of urea to avoid warm and wet conditions can help minimize N losses.

d) Right Timing

The demand for a nutrient by a growing crop generally varies 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 a desirable goal. Plants subject to a deficiency during specific periods of growth may not recover to achieve full yield potential. An example of this is the impact of an early season P deficiency on corn, where an absence of adequate P during the first few weeks of growth limit root formation by the crop and can ultimately delay maturity and affect yield (**Table 2**, Gordon, 2003).

Table 2. Nitrogen and P rate effect on number of thermal units from emergence to mid-silk. Phosphorus starter (2x2) was applied at 30 lb P_2O_5/A (Kansas, Gordon, 2003).

N Rate lb/A	Without P	With P	Difference
	- - - - - - Thermal Units to Midsilk - - - - - -		
0	1,386	1,290	96
40	1,362	1,280	82
80	1,320	1,210	110
120	1,318	1,208	110
160	1,318	1,210	108
200	1,316	1,210	106
Average	1,337	1,235	102

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 sensing, aerial imagery, or yield mapping. Some or all of these measurements can be used to divide fields into management zones or units that can be fertilized independently (Koch et al., 2004). This form of site-specific fertility management increases the odds that nutrient needs are properly identified and appropriate corrective fertilizer applications are made only where required. 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 biomass and /or greenness as an indication of N sufficiency (Raun et al., 1999). These sensors use a reference strip 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.

3. 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. 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.

a) Nutrient Leaching

Retention of soluble nutrients in the rooting zone of crops ensures efficient recovery and efficient use in crop production systems. Leaching occurs when excessive residual nutrients are left in the soil profile and moved below the rooting zone by precipitation or irrigation. 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. While there are no reported incidences of P leaching through fertilizer use at soil test recommended rates, leached P has been reported with the application of livestock manure at rates grossly in excess of crop requirements.

Water is, in most years, the factor that limits yields the most in the Great Plains. Therefore some supplemental irrigation, where available, is needed to produce high yields in most years. Furrow irrigation is the least efficient method of delivering water to a field and has thus largely fallen out of favor. Center pivot or linear sprinkler systems are much more efficient and precise irrigation tools and are the most commonly used systems on the Great Plains today. A newer and even more efficient method of irrigation is being rapidly adopted in some areas of the Great Plains… subsurface drip irrigation. The sprinkler type and subsurface drip systems allow easy application of N fertilizer with irrigation (fertigation) throughout the season, and when used in combination with weather station and crop data (PET, soil moisture, etc.) these systems enable the grower to maximize efficiency of water and nutrient inputs with relatively no risk of N leaching.

While excess nutrients can result in leaching, withholding needed fertilizer may be more damaging to the environment than applying fertilizer. When N is applied alone, and not in balance with required P, more leached N has been found below the crop rooting zone (Schlegel et al., 1996). The balance of applied fertilizer N with P improved the recovery of N by the crop and removal in the grain, reducing the residual N left in the soil for leaching below the rooting zone (**Figure 3**).

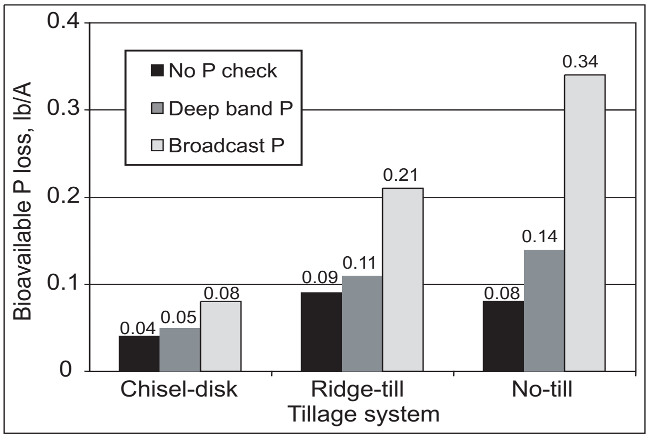

Figure 3. Effect of N and P fertilization on residual NO_3-N in the upper 10 ft. after 30 years of irrigated corn production (Kansas, Schlegel et al, 1996).

b) Conservation Tillage, Soil Erosion, and Carbon Sequestration

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 improved 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. Positive effects of N fertilization on soil organic carbon were clearly demonstrated in a long-term dryland annual cropping study under no-till conditions in Colorado (Halvorson and Reule, 1999). Nitrogen fertilization significantly increased crop residue inputs to the soil, resulting in increases in soil organic carbon after 11 crops. The increase in organic matter with increasing N fertilization rate decreased soil bulk density and contributed to improving soil quality. Carbon sequestration efficiency was improved by appropriate N fertilization. A good fertility program helps sequester atmospheric CO_2 into soil organic carbon by increasing plant growth and, subsequently, returning more organic C to the soil for storage as soil organic matter.

c) Field Buffer Strips

The movement of N and P into surface waters with eroded soil poses a serious threat to aquatic ecosystems. While some nutrients are required for ecosystem function, too much can lead to a decline in productivity. Stopping soil erosion from agricultural lands has been a high priority for all farmers. Any eroded soil means loss of nutrients, organic matter, and future crop productivity. The adoption of conservation practices such as no-till and buffer strips adjacent to surface water have been shown to reduce this unwanted movement of nutrients. In many instances where no-till field management has been adopted, soil erosion and water runoff have been significantly reduced.

Taking Stock of Your Fertilizer Management

It's time to take stock of how you measure up in the use of fertilizer BMPs. Using the reference chart in this document, evaluate the number of categories under which you rank in the top two categories. If you cannot demonstrate a suitable fit in these top two categories you may want to re-evaluate some of your current management practices. Ensuring that we have either achieved, or are working towards fertilizer BMPs is a measure of our production system success.

Many farmers in the Southern and Central Great Plains Region have demonstrated a rapid adoption of fertilizer BMPs. Soil testing, realistic yield goals based on available water, balanced fertilizer application, subsurface banding of fertilizer, and use of reduced or no-till systems all demonstrate excellent progress to date. While continued adoption of BMPs is critical, those which have positive economic impact continue to be the most rapidly adopted. ■

References

Black, C.A. 1993. Soil fertility evaluation and control. CRC Press, Boca Raton, FL.

Gordon, W.B. 2003. Nitrogen and phosphorus management for corn and soybeans grown in rotation. Better Crops. Vol. 87. No. 1. p. 4-5. (Available online at http://www.ppi-ppic.org/ppiweb/bcrops.nsf/$webindex/22C75CE17E3755C185256CBB007A2DD9/$file/03-1p04.pdf) (Verified 30 Dec. 2005.)

Gordon, W.B. 2005. Maximizing irrigated corn yields in the Great Plains. Better Crops. Vol. 89. No. 2. p. 8-10. (Available online at http://www.ppi-ppic.org/ppiweb/bcrops.nsf/$webindex/384E4BAB8B896CDC85256FEB00693E7B/$file/05-2p08.pdf) (Verified 30 Dec. 2005.)

Halvorson, A.D. and C.A. Reule. 1999. Long-term nitrogen fertilization benefits soil carbon sequestration. Better Crops. Vol. 83. No. 4. p. 16-20. (Available online at http://www.ppi-far.org/ppiweb/bcrops.nsf/$webindex/3C9583E0CE774DE6852568EF00579DCA/$file/99-4p16.pdf!open) (Verified 30 Dec. 2005.)

Irrigation Research Foundation. 2006. [Online]. Available at http://www.irf-info.com/ (Verified 4 Jan. 2006.)

Janssen, K.A., G.M. Pierzynski, P.L. Barnes, and R.G. Rogers. 1999. Best management practices to minimize phosphorus runoff losses from cropland. Better Crops. Vol. 83. No. 2. p. 12-14. (Available online at http://www.ppi-ppic.org/ppiweb/bcrops.nsf/$webindex/1C99D8E0116DF4DF852568EF005C6F70/$file/99-2p12.pdf) (Verified 30 Dec. 2005.)

Koch, B., R. Khosla, W.M. Frasier, D.G. Westfall, and D. Inman. 2004. Economic feasibility of variable-rate nitrogen application utilizing site-specific management zones. Agron. J. 96: 1572-1580.

Kansas State University. 2004. Agronomy field research. Report of progress 928. Manhattan, KS.

Leikam, D.F., R.E. Lamond, and D.B. Mengel. 2003. Soil test interpretations and fertilizer recommendations. MF-2586. Kansas State Univ. Agric. Exp. Stn. and Coop. Ext. Manhattan, KS. (Available online at http://www.oznet.ksu.edu/library/crpsl2/mf2586.pdf) (Verified 30 Dec. 2005.)

Ortega, R.A., D.G. Westfall, and G.A. Peterson. 1997. Variability of phosphorus over landscapes and dryland winter wheat yields. Better Crops. Vol. 81. No. 2. p. 24-27. (Available online at http://www.ppi-ppic.org/ppiweb/bcrops.nsf/$webindex/55B51B86141104D4852568F100616281/$file/97-2p24.pdf) (Verified 30 Dec. 2005.)

Raun, W.B., G.V. Johnson, M.L. Stone, J.B. Solie, W.E. Thomason, and E.V. Lukina. 1999. In-season prediction of yield potential in winter wheat. Better Crops. Vol. 83. No. 2. p. 24-25. (Available online at http://www.ppi-ppic.org/ppiweb/bcrops.nsf/$webindex/1EEC1075CC37FD95852568EF005D36DB/$file/99-2p24.pdf) (Verified 30 Dec. 2005.)

Roberts, T.L. and J.T. Harapiak. 1997. Nutrient management and one-pass seeding in the Canadian Praries. Proceedings of the Western Nutrient Management Conference. Salt Lake City, UT. Potash & Phosphate Institute.

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.

Stewart, W.M. 2001. Balanced fertilization increases water use efficiency. Potash & Phosphate Institute. Publ. RN 01049. (Available online at http://www.ppi-ppic.org/ppiweb/ppinews.nsf/$webcontents/736A94E12DC4646D85256A0300522826/$file/Water+Use+Efficiency.pdf) (Verified 30 Dec. 2005.)

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