KANSAS STATE UNIVERSITY FERTILIZER RECOMMENDATION REVISIONS

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INTRODUCTION

Soil testing has long been recognized as the cornerstone for developing cost effective, efficient and environmentally sound nutrient management programs. However, there are still many acres that do not have a sound soil test history. This indicates that there is still much education needed to increase farmer acceptance of soil testing in developing agronomically sound and profitable nutrient management programs. At the same time, USDA is placing increased emphasis on nutrient management planning (NMP) as a requirement for participation in some targeted farm programs. An indirect result of USDA's increased emphasis on nutrient management is the positioning of land grant University crop nutrient recommendations as regulatory tools by some agencies. Most soil fertility specialists would agree that nutrient rate recommendation guidelines should be viewed more as a decision aid tool for producers rather than as a regulatory decision making tool for regulators.

Recently, Kansas State University (KSU) crop nutrient recommendations were revised in order to more adequately address changes in the ways production agriculture operates today. The intent of these revisions was not to question the research database upon which KSU nutrient recommendations are based, but rather to implement an overall framework that incorporates the following factors:

- Flexibility. When appropriate, provide options that meet the short-term and long-term expectations of individual producers while providing for environmental stewardship.
- Education. Recommendations should be a part of an overall educational program, not simply a way of calculating an answer or looking values up in a table. Education stressing the strengths and limitations of soil testing as well as emphasizing the producer's role in developing nutrient management programs for individual fields will hopefully increase the overall credibility and use of soil testing.
- Principles. Take the black box out of the soil testing/recommendation development process by incorporating known soil fertility principles. Wherever possible, directly include factors which affect crop nutrient requirements rather than building them into a 'simpler' equation (e.g. soil organic matter N contributions, tillage system/depth).
- Simplify. Where possible, simplify recommendation process/equations in order to allow for easy integration into crop management software used by producers and their advisors.

RECOMMENDATIONS

Liming Recommendations. In addition to standard lime recommendations for different crops and areas of the state to correct soil acidity problems for the long term, an additional option is provided for situations in which a shorter term solution is needed. Generally, it is recommended that all crops/soils in southeast Kansas and alfalfa/clover production fields in northeast Kansas be limed to a target soil pH of 6.8 if the initial pH is less than 6.4. The soils in these areas are

typically shallow or have neutral to acidic subsoils. For non-legume crops in northeast Kansas and all crops in the central and western parts of the state, it is suggested that the soils be limed to a target pH of 6.0 if the soil pH is less than 5.8. Both of these liming programs will correct the acidic soil conditions several years into the future.

However, lime is not readily available in most of central and western Kansas and is consequently very expensive relative to other areas of the country. Depending on specific lime costs, landlord/tenant relationships and cash flow considerations it may not be feasible to apply enough lime to correct soil pH problems for the longer term. For these circumstances, an additional option of liming soils with much lower rates to a target pH of about 5.5 is provided.

Table 1. Kansas State University Lime Recommendations

	Lime Recommendations (Lb ECC/A) [1]		
Buffer pH	Target pH = 6.8	Target pH = 6.0	Target pH = 5.5
	lbs ECC/acre		
7.4	0	0	0
7.2	750	375	250
7.0	1750	875	500
6.8	3000	1500	750
6.6	4500	2250	1000
6.4	6250	3125	1500
6.2	8250	4125	2000
6.0	10250 *	5125	2500
5.8	12500 *	6250	3000
5.6	15250 *	7625	3750
5.4	18000 *	9000	4500
5.2	20000 *	10375 *	5250

Target pH of 6.8 = [[25620 - (6360 x Buffer pH) + (Buffer pH x Buffer pH x 391)] x Depth (inches)]
Target pH of 6.0 = [[12810 - (3180 x Buffer pH) + (Buffer pH x Buffer pH x 196)] x Depth (inches)]
Target pH of 5.5 = [[6405 - (1590 x Buffer pH) + (Buffer pH x Buffer pH x 98)] x Depth (inches)]

Nitrogen Recommendations. Wheat nitrogen (N) recommendations are summarized in Table 2, other crops are similar. Total crop N requirement is determined by multiplying the field yield goal by a crop N factor (lbs N/unit crop yield). The new crop N factors are higher than KSU recommendations in the past, but more adjustments are made. For example, the crop N factor for corn is 1.6 lbs N/bu and 2.4 lbs N/bu of wheat. Previously, the crop N factors were 1.3 and 1.75 lbs N/bu for corn and wheat, respectively. New crop N factors for other crops include 1.6 lbs N/bu for grain sorghum, 7.5 lbs N/cwt for sunflowers, 10.67 lbs N/ton for corn/sorghum silage and 1.3 lbs N/bu for oats. The total N requirement each crop is then adjusted for specific fields.

As in the past, KSU N recommendations are adjusted for available profile nitrate-N, previous legume crops, irrigation water, manure, grazing removal, and other N contributions. In addition, the new KSU N recommendations are directly adjusted for soil organic matter contributions, tillage system (wheat) and in some cases, non-legume previous crops (wheat following grain sorghum or sunflowers). For warm season crops (e.g. corn, sorghum), about 20 pounds of available N per acre are expected to be mineralized for each 1.0 percent soil organic matter while only 10 pounds of available N is expected to be mineralized for each 1.0 percent soil organic matter for cool season crops (Table 2).

Table 2. Kansas State University Wheat Nitrogen Recommendations

Fertilizer N Required At Various Yield and Soil Organic Matter Levels Assuming Profile N Test Is Not Used (includes 30 Lb N/A residual default) [1]

Yield Goal	Soil Organic Matter Content (%)						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0
(Bu/A)	- - - - - - - LbN/A - - - - - - -						
30	32	27	22	17	12	7	2
40	56	51	46	41	36	31	26
50	80	75	70	65	60	55	50
60	104	99	94	89	84	79	74
70	128	123	118	113	108	103	98

N Rec [2] = Yield Goal x 2.4 - % SOM x 10 - Profile N - Other N Adj. + Previous Crop Adj. + Tillage Adj. + Grazing Adj.

[1] Total N requirements presented include only Yield Goal and Soil Organic Matter Adjustments assuming profile N test not used. N rate should also be adjusted for Previous Crop, Tillage, Grazing and Other Appropriate N Rate Adjustments (Table XY).

[2] A minimum fertilizer N application of 30 Lb N/A may be appropriate for early crop growth and development.

Phosphorus and Potassium Recommendations. Historically, land grant Universities have generally provided a single rate recommendation for nutrients such as phosphorus (P) and potassium (K). Depending on the particular University in question, these nutrient rate recommendations are generally based on two widely recognized approaches to managing soil and fertilizer P and K – the nutrient sufficiency approach and the build-maintenance approach. In the past, KSU phosphorus and potassium recommendations were largely based on the nutrient sufficiency approach. As we evaluated and discussed our fertilizer recommendations, it became apparent that we needed to also provide growers the guidelines for the build-maintenance approach. It is often stated that the nutrient sufficiency approach is most appropriate for the Great Plains and western states since yields are more often limited by available moisture than areas farther east, where the build-maintenance approach has been widely used. However, these overly broad assumptions do not always fit individual growers, fields, and other situations.

The goal of a nutrient sufficiency based soil fertility program is to apply just enough P and/or K to maximize profitability in the year of application, but minimize nutrient applications and fertilizer costs, each year. While inherent variability in nutrient response, both field-to-field and year-to-year, may result in more or less nutrient actually being required for maximum profitability in a given year than is recommended, near optimum rates will be recommended over the longer term. Unless initial soil test levels are high and the soil can supply all the nutrient needs of the crop when this approach is adopted, little year-to-year flexibility in nutrient application exists and nutrient application is required every year in order to eliminate profit robbing nutrient shortages. Specific nutrient application methods, such as the use of band application, may also be needed for maximum nutrient response.

Nutrient sufficiency recommendations are based on long-term soil test calibration field data. In an attempt to address the complicated, constantly changing issue of marginal return on fertilizer investment in the year of application, these recommendations are typically developed to provide 90 to 95% of maximum yield. Crop response and recommended nutrient application rates are highest at very low soil test levels, while recommended nutrient application rates decrease to zero as the soil test level increases to a 'critical' soil test value. The critical level is the soil test value at which the soil is normally capable of supplying sufficient amounts of P and/or K to achieve 90-95% of maximum yield. For nutrient sufficiency recommendations, soil test values are not viewed as a managed variable with little or no consideration of future soil test values. When this system is followed for long periods of time, soil test values eventually

stabilize at 'low', crop responsive levels, with recommended application rates being approximately equal to crop removal.

The objective of build-maintenance fertility programs is to manage a controllable variable, P and/or K soil test levels. Build-maintenance fertility programs are not intended to provide optimum economic returns in any given year, but rather attempt to minimize the possibility of P and/or K limiting crop growth while providing near maximum yield, high levels of grower flexibility and good economic returns over the long-run. At low soil test values, build-maintenance recommendations are intended to apply enough P and/or K to meet both the nutrient needs of the immediate crop and to build soil test levels to a non-limiting value, above the critical level. This build-up of soil test values occurs over a planned period of time (typically 4 to 8 years). Once the soil test value exceeds the critical value, nutrient recommendations are then made to maintain the soil test levels in a target, or management range. The soil test target range is typically at and slightly above the critical soil test value, where the soil can generally provide adequate nutrients to meet the nutritional needs of growing crops ('medium' to 'high' levels) without additional fertilizer. While nutrient applications are required for optimum yields below the critical level, farmers have great flexibility as to when fertilizer is applied once soil tests are in the target range. Above the critical level the soil is largely capable of supplying the nutrients needed in a given year. Farmers can thus choose to apply fertilizer annually or to combine applications and only apply the fertilizer every two or three years. This provides flexibility to manage both time and cash flow. It also allows more efficient utilization of the nitrogen in common P fertilizer products (ammonium phosphates; DAP, MAP, APP) by directing the applications to crops normally requiring additional nitrogen, such as corn or grain sorghum.

In recent years agronomists have become increasingly concerned over the environmental impact of nutrient programs, particularly P fertilization. So, the upper end of the target or management zone is commonly determined by a combination of agronomic, economic and environmental factors. When soil test values exceed the target range, the probability of crop response is relatively low while the potential for environmental concerns begins to increase. No P and/or K is normally recommended beyond the target range with the exception of small amounts of starter fertilizers. The disadvantage of soil build-maintenance programs when soil test levels are below the critical soil test level (the crop responsive range), is that required application rates are normally higher than those recommended for nutrient sufficiency programs.

At low soil test levels there is a greater possibility that the crop will respond to fertilizer, and that the fertilizer application will be profitable in the year of application. However, the probability that P and/or K nutrition may limit yield and profitability in any given year is also higher. At higher soil test levels there is less chance that P and/or K nutrition will limit crop yield in a given year, but the probability that a fertilizer application will be profitable in the year of application will also be lower. It should be an individual producer's decision on how to weigh and manage these various risks/uncertainties.

Higher soil test values provide for greater flexibility in future P and K management plans (e.g. application rate, method and frequency) and a greater cushion in the event of adverse environmental conditions (e.g. very wet, very dry, etc.) or financial conditions (e.g. unfavorable crop/fertilizer prices, cash flow, etc.). All things being equal, most producers would prefer to have soil P and K tests above the critical level (but not excessively high) as opposed to in the low, crop responsive soil test range, because of greater flexibility in nutrient management options. There is, however, a cost associated with building or maintaining soil test levels in the medium-high range. Again, it should be the individual producer's decision on how much to value this flexibility.

Table 3. Kansas State University Wheat P and K Recommendations

Sufficiency P Recommendations For Wheat [1]

Bray P-1	Yield Goal (Bu/A)				
	30	40	50	60	70
(ppm)	Lb P_2O_5/A				
0-5	50	55	60	60	65
5-10	35	40	40	45	45
10-15	20	25	25	25	30
15-20	15	15	15	15	15
20+	0 [2]	0 [2]	0 [2]	0 [2]	0 [2]
Crop Removal [3]	15	20	25	30	35

Sufficiency K Recommendations For Wheat [1]

Exch. K	Yield Goal (Bu/A)				
	30	40	50	60	70
(ppm)	Lb K_2O/A				
0-40	60	60	65	65	65
40-80	35	40	40	40	40
80-120	15	15	15	20	20
120-130	15	15	15	15	15
130+	0	0	0	0	0
Crop Removal [3]	9	12	15	18	21

Wheat Sufficiency P Rec = [46 + (Yield Goal x 0.42) + (Bray P x -2.3) + (Yield Goal x Bray P x -0.021)]
Wheat Sufficiency K Rec = [62 + (Yield Goal x 0.24) + (Exch K x -0.48) + (Yield Goal x Exch K x -0.0018)]

Phosphorus Build-Maintenance Wheat Recommendations [5]

Bray P1	4 Year Build Timeframe			6 Year Build Timeframe			8 Year Build Timeframe		
	Yield (Bu/A)			Yield (Bu/A)			Yield (Bu/A)		
Soil Test	40	60	70	30	50	70	30	50	70
(ppm)	Lbs P2O5/A			Lbs P2O5/A			Lbs P2O5/A		
0-5	99	109	114	73	83	88	59	69	74
5-10	76	86	91	58	68	73	48	58	63
10-15	54	64	69	43	53	58	37	47	52
15-20	31	41	46	28	38	43	26	36	41
20-30 [4]	20	30	35	20	30	35	20	30	35
30+	0 [2]	0 [2]	0 [2]	0 [2]	0 [2]	0 [2]	0 [2]	0 [2]	0 [2]

Potassium Build-Maintenance Wheat Recommendations [5]

Exch. K	4 Year Build Timeframe			6 Year Build Timeframe			8 Year Build Timeframe		
	Yield (Bu/A)			Yield (Bu/A)			Yield (Bu/A)		
Soil Test	30	50	70	30	50	70	30	50	70
(ppm)	Lbs K2O/A			Lbs K2O/A			Lbs K2O/A		
0-40	257	263	269	174	180	186	133	139	145
40-80	167	173	179	114	120	126	88	94	100
80-130	65	71	77	47	53	59	37	43	49
130-160 [4]	9	15	21	9	15	21	9	15	21
160+	0	0	0	0	0	0	0	0	0

Phosphorus Build-Maintenance Rec = $\frac{\{(20 - \text{Current P Soil Test}) \times 18\}}{\text{Years To Build}}$ + P_2O_5 Removal In Crop

Potassium Build-Maintenance Rec = $\frac{\{(130 - \text{Current K Soil Test}) \times 9\}}{\text{Years To Build}}$ + K_2O Removal In Crop

[1] Crop P & K recommendations are for the total amount of broadcast and banded nutrients to be applied. At low to very low soil test levels applying at least 25 to 50% of total as a band is recommended.

[2] Application of a NP, NPK or NPKS starter fertilizer may be beneficial regardless of P soil test level, especially for cold/wet soil conditions and/or high surface crop residues. Do not exceed N + K_2O guidelines for fertilizer placed in direct seed contact.

[3] Crop removal numbers provided for comparitive purpose only - 0.50 lb P_2O_5 and 0.30 lb K_2O per bushel of harvested wheat. If crop removal exceeds nutrient applications, soil test levels are expected to decline over time.

[4] Recommended ammounts of P_2O_5 and K_2O are based on crop nutrient removal at the indicated yields (0.50 lb P_2O_5 / bu and 0.30 lb K_2O / bu).

[5] Four, six and eight year timeframes below are examples only. Build programs can be over longer timeframe, however, build-maintenance recommendations should not be less than crop sufficiency based fertility programs.

Over an extended period of time, the two systems (sufficiency and build-maintenance) provide a grower the choice between a system which recommends lower nutrient application rates at low soil test levels, but requires annual fertilizer application (nutrient sufficiency programs), versus investing in higher rates for 4 to 8 years in order to gain the flexibility and potential cost savings of making multi-year applications when it is most convenient and economical (build-maintenance programs). While the short-term difference in cost between the between the two programs may be sizeable, the benefits from flexibility in the overall fertility program, reduced application costs, improved timeliness, and cash management can make the investment in build-maintenance programs worthwhile. Once a grower understands the two approaches, he/she can decide if that cost is a reasonable investment.

As mentioned earlier, another factor which has become more important in recent years is the possible requirement of Nutrient Management Planning for some targeted USDA farm programs. Typically, these plans require land grant University based crop nutrient recommendations. Previous KSU recommendations would have provided only a single rate recommendation that would effectively eliminate flexibility for producers developing individualized nutrient management plans. In essence, a key management decision would be taken out of producers hands. This is undesirable from KSU's and the individual farmer's perspective.

With the new KSU recommendations, farmers are able to maintain flexibility in developing individual nutrient management plans while providing for environmental protection and maintaining compliance with NRCS farm program provisions. Table 3 provides an example summary of KSU P and K recommendations for wheat. Other crops are handled similarly. Both nutrient sufficiency and build-maintenance guidelines are provided, allowing individual producers to choose the approach they feel is most appropriate for specific field conditions. Estimated crop removal values are provided for informational purposes with nutrient sufficiency recommendations, starter fertilizer applications may be suggested regardless of P and/or K soil test (if starter attachments available) and including some portion of the overall fertility program as a band application for fields with low soil test values are a part of the recommendations.

Zinc, Chloride, Sulfur and Boron. Kansas State University also provides interpretations for zinc, chloride, sulfur and boron. Interpretations and recommendations for these nutrients can be found in the KSU publication MF-2586, 'Soil Test Interpretations and Fertilizer Recommendations', which is available from the KSU Research & Extension web site (http://www.oznet.ksu.edu/, http://www.oznet.ksu.edu/library/crpsl2/MF2586.pdf).

SUMMARY

We believe nutrient management programs must be tailored to specific conditions affecting each field for individual growers. It is likely that individual producers may adopt different management systems, even if they are facing similar crop/field situations. It is up to the individual producer to decide what management program best fits each field and/or situation. Where appropriate, recommendation programs should provide for options/flexibility, should easily integrate into crop management software used by producers/crop advisors, and basic soil fertility principles should be incorporated as directly as possible in order to easily integrate the resulting recommendation numbers with an overall nutrient management educational program.