Fertilization Based on Sufficiency, Build-up and Maintenance Concept

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Introduction

The primary nutrients that are deficient in Oklahoma are nitrogen (N), phosphorous (P) and potassium (K). Fertilizer recommendations should be based on the results from soil tests that determine what type of deficiency exists in the field. When a group of producers were asked if soil testing would help improve crop yields, 82 percent responded positively. But when the same group was asked if they used soil test routinely; only 28 percent replied "yes" (Kinsey, 2002).

There are different approaches soil testing labs (commercial and public) and consultants may use when making fertilizer recommendations. Some laboratories use the sufficiency concept, while others use the maintenance, build-up or a combination of all three approaches. For example, Oklahoma State University has been using the sufficiency concept for immobile nutrient recommendation, while Kansas State University provides guidelines for both the sufficiency and the buildup-maintenance approach.

This publication describes; different approaches for making fertilizer recommendations so one can understand why there are discrepancies among the recommendations of different labs, and how to adjust fertilizer practices based on market conditions. However, Oklahoma State University Soil Testing Lab does not intend to change from the sufficiency approach.

Sufficiency – Fertilizing the crop, rates based on likelihood of achieving a yield response
Build-Maintain – Fertilizing the soil, rates based on increasing soil test values to defined level then adjusting the rate to maintain soil test values at the critical level.

Sufficiency Approach

The requirements for immobile nutrients are not related to yield goal, like mobile nutrients such as nitrogen and sulfur (Zhang and Raun, 2008). Instead, the requirements of immobile nutrients are functions of the concentration of plant available nutrients in the soil. In general, a plant can only extract immobile nutrients, such as P and K, from the soils near the root surface. Thus, the amount extracted by the plant is limited by the concentration at the root-soil interface.

For immobile nutrients, nutrient level is presented as a percent sufficiency based on soil test value. Percent sufficiency for an immobile nutrient can be expressed as a percentage of the potential yield when the nutrient is limited and independent of the environment. For example, the regional yield potential for winter wheat is 50 bu ac^{-1}, but the soil test indicates the P level is 80 percent sufficient then the maximum yield you should expect is 40 bu ac^{-1} (50 x 0.80).

Each crop has a specific sufficiency index and a recommended application rate for each nutrient. The goal of the sufficiency approach is to apply enough fertilizer to maximize profitability in that given year of application, while minimizing nutrient applications and fertilizer costs at the same time. Of the management strategies, the sufficiency concept will, in general apply the least amount of total nutrient. Many remember how the sufficiency concept works by saying that it "fertilizes the crop."

Yield response trials must be preformed to develop sufficiency levels. In these trials, the point at which there is no increase in yield is identified as the critical level. Oklahoma State University used yield data collected from across Oklahoma to create the calibration table for sufficiency levels of available nutrients (SLAN). Each soil test index is associated with a sufficient level based on a critical value for each nutrient (Zhang, & Raun, 2006). Table 1 shows soil test P index, the sufficiency level and P_2O_5 recommendations for many of the common crops grown in Oklahoma.

A positive aspect of the sufficiency concept is that yields are maximized while annual inputs are minimized. However, applications will need to be made every year to maintain those yield levels. Fertilization based on sufficiency levels is well suited for short term leases.

Maintenance

According to the maintenance concept, nutrients that have been removed with the crop at harvest should be

Table 1. Phosphorus fertilizer recommendations for selected crops grown in Oklahoma using sufficiency concept based on five soil test P (STP) levels.

Phosphorus Requirements										
STP	*Small Grains*		*Grain Sorghum*		*Corn*		*Cotton*		*Canola*	
Test Index	*Percent Suff*	*P_2O_5 (lbs/A)*	*Percent Suff*	*P_2O_5 (lbs/A)*	*Percent Suff*	*P_2O_5 (lbs/A)*	*Percent Suff*	*P_2O_5 (lbs/A)*	*Percent Suff*	*P_2O_5 (lbs/A)*
0	25	80	40	60	30	80	55	75	25	80
10	45	60	60	50	60	60	70	60	45	60
20	80	40	80	40	80	40	85	45	80	40
40	90	20	95	20	95	20	95	30	90	20
65+	100	0	100	0	100	0	100	0	100	0

replaced. Fertilizer is then applied, based on the amount of nutrients removed from the field, so that the soil nutrient level is maintained (Vitosh et al., 1995). For example, winter wheat removes 0.50 lbs of P_2O_5 for every bushel harvested, so a 40 bu ac^{-1} yield would require approximately 20 lbs P_2O_5 per acre, see Table 2. The maintenance concept does not recommend application when soil nutrient levels are above the critical level. Above the critical soil test level, the soil will be able to supply the nutrients required by the crop and no fertilizer response would be expected. An assumption of the maintenance concept is that there will be no change in soil test values if crop removal is used for the maintenance rate.

Table 2. Estimates of nutrient removal in the harvested portion of the crop.

Crop	*Unit*	*P_2O_5*	*K_2O*
Wheat	lb/bu	0.50	0.30
Corn	lb/bu	0.44	0.29
Grain Sorghum	lb/cwt	0.75	0.39
Canola	lb/bu	0.91	0.46
Soybean	lb/bu	0.80	1.40
Alfafla	lb/ton	15.0	60.0
Cotton	lb/bale	12.0	14.0

Source: IPNI http://npk.okstate.edu/documentation/various/IPNI%20Removal%20Master%20101028.pdf

Build-up

This approach is one where the soil, rather than the plant is fertilized. The concept is based on applying nutrients in excess of the nutrients removed by the crop to build the concentration to the point where they will not be limiting. This method of fertilization has been practiced on lands that are owned or in long-term lease to ensure that the renter will "reap the fruits" of the long-term fertilization. One of the expected fruits is the potential of avoiding fertilization during times when fertilizer prices are high.

The build-up of soil test values occurs during a planned period of time, usually four to eight years (Leikham et. al, 2003). Depending on the economic situation of the farmer, the farmer might choose a slow or fast build-up of P and K. Long term build-up programs help farmers manage their finances by spreading fertilizer costs through several years.

Build- up and Maintenance

In most literature the concepts of build-up and maintenance are mentioned together. In the central regions, Kansas State University provides 'build maintenance' guidelines based on their research. The build-up and maintenance philosophy has been applied since the 1940's (Hochmuth and Hanlon, 2010) and is most suitable for immobile nutrients like P and K (Johnston et al., 2006). This means P and K would be raised to the critical soil test levels, by applying fertilizer during a long period of time, avoiding a one-time high application rate (Johnston et al., 2006). Once the critical soil test level is reached, fertilizer recommendations will be based on maintenance.

Figure 1 represents a model for a tri-state fertilizer recommendation by Ohio State University based on studies conducted during a 40-year period. The most important

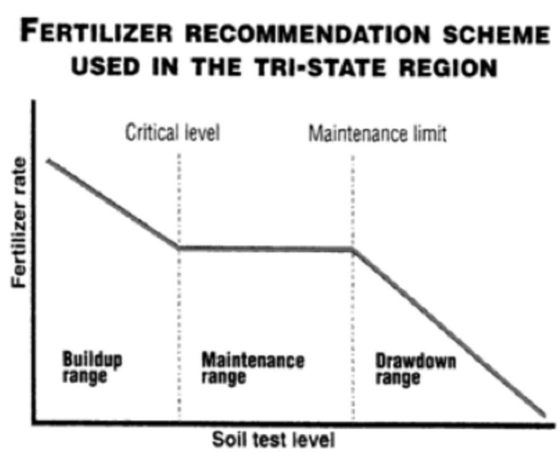

Figure 1: Build-up maintain fertilizer scheme suggested by the Ohio State University.

Table 3. Sufficiency and build-maintenance fertilizer P and K rate recommendations for corn and wheat production.

Crop	Yield goal	Soil test result		Sufficiency recommendations		Build-maintenance recommendations 4-yr build timeframe	
		Mehlich 3 P ppm	NH_4OAc K ppm	P_2O_5 lb/ac	K_2O lb/ac	lb/ac	lb/ac
Corn	250	15	100	25	30	105	135
	250	25	130	0	0	60	65
Wheat	40	15	100	15	15	45	80
	40	25	130	0	0	0	15

component of this model is the establishment of a critical level. This critical level is the same value that is established as the 100 percent level for the sufficiency concept.

Discussion

Different labs and consultants can give different fertilizer recommendations based on the management concept used. The best approach for making fertilizer recommendations depends on several factors such as type of soil, economics and cropping systems.

The combination between the build-up and maintenance concept is widely used. Kansas State University has provided an excel file allowing the user to see nutrient recommendation based on both the sufficiency and build-maintenance concept. As seen in Table 3, P and K recommendations based on the build-maintenance concept are higher than the recommendations based on the sufficiency concept. The sufficiency concept recommends no P for both corn and wheat at a Mehlich 3 soil test of 25 ppm (equivalent to OSU's STP of 50). On the other hand, the build-maintenance recommends 60 lb ac^{-1} of P_2O_5 and 65 lb ac^{-1} of K_2O. In terms of annual input cost it is easy to see the difference.

Regardless of the approach, producers should take soil samples on a regular basis, at least every three to five years, to ensure the level of each nutrient in the soil is known and fertilizer use efficiency and yields are maximized.

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