REVIEW OF FERTILIZER PLACEMENT FOR CORN AND SOYBEANS

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Introduction As with any agricultural technology, the value of an input will often be site specific, where the application of and response to a particular management practice depends on factors that vary between locations and/or years. Nutrient management decisions should be fundamentally based on those site specific factors that dictate a particular placement option for maximum productivity and profit, with minimal risk to the environment.

When evaluating nutrient placement options, it is critical to assess the underlying agronomic principles and reasons for the potential advantage of one placement method over another. Therefore, effectively documenting the value of a specific placement method by using supporting crop response data requires an adequate description of the mechanisms involved in the nutrient placement response. Understanding principles of nutrient reactions in soils and the relevant interactions between growing season environment (rainfall amount, pattern, etc), crop factors (species, planting date, etc), tillage and residue management, and other factors influencing plant vigor and productivity guide nutrient placement decisions.

Placement Options The various placement options can be characterized by a simple matrix of application time by placement relative to the soil surface or seed (Figure 1). Specific application times refer to *before*, *at*, or *after planting*, while placement is characterized by *surface* or *subsurface* application (foliar or fertigation options not shown).

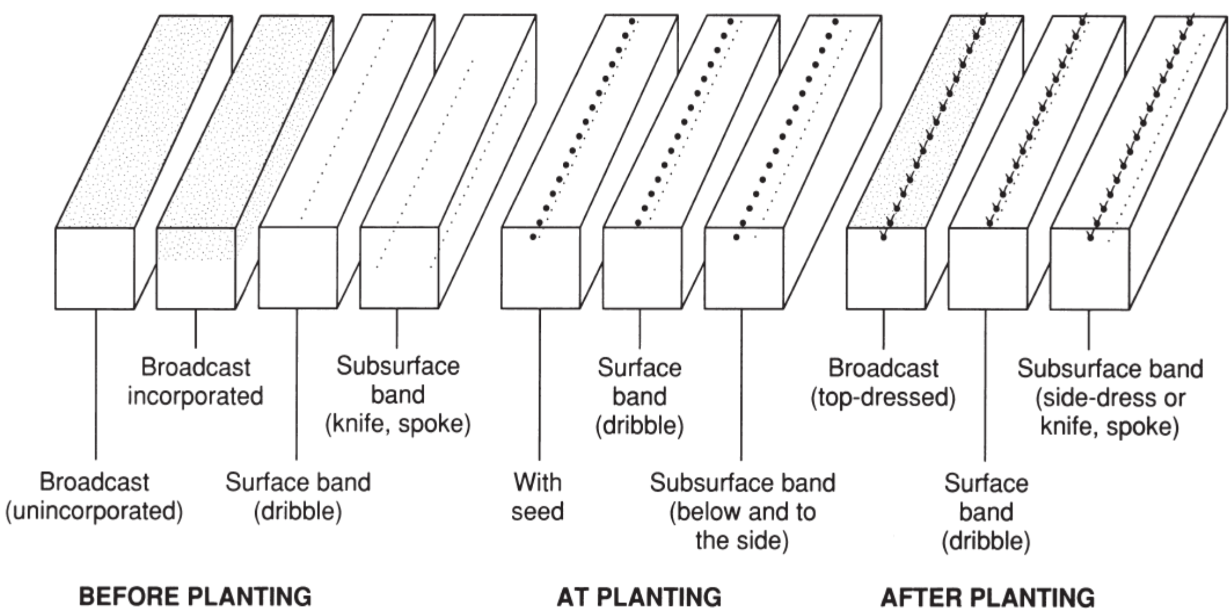

Figure 1. Classification of nutrient placement options based on application time and position relative to the soil surface or the seed.

Placement Decision Factors

Fertilizer Cost Fertilizer costs reached historic highs in 2008. Although recent changes in energy costs, product supply, and other factors will decease fertilizer prices, the cost per unit of applied nutrient will likely remain high, compared to several years ago (Figure 2). Since nutrients will remain one of the larger input costs in a production system. It is relatively easy to assess the influence of fluctuating fertilizer and grain prices on optimum nutrient rates. Using known functional relationships between corn yield response to increasing N rate, economic optimum N rates can be quantified.

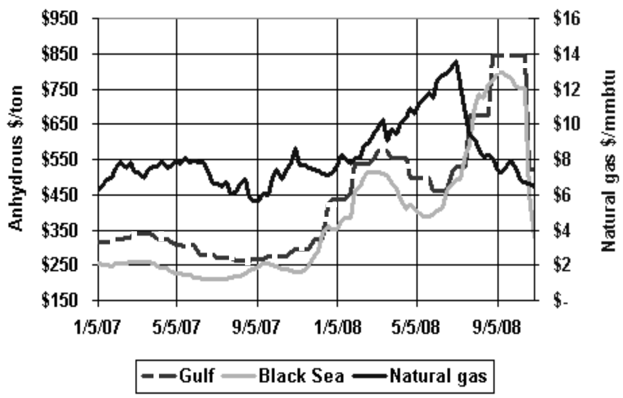

Figure 2. Recent changes in natural gas and anhydrous NH_3 prices (IFA, 2008).

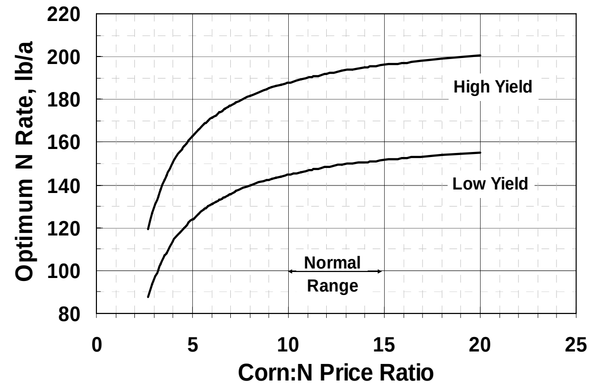

Figure 3. Influence of corn : N price ratio on economic optimum N rate (Havlin and Benson, 2006).

With corn, the crop price:N cost ratio typically varies between 10:1 and 15:1 (i.e., 10:1 ratio results from $5.00/bu:$0.50/lb N). Under this range in price ratios, the N rate for maximum economic corn yield varies only slightly. However, when N fertilizer price increases significantly and crop price remains constant or decreases, the economic optimum N rate decreases (Figure 3). While optimum N rates depend on prices, it is important that as nutrient costs increase, the most efficient placement methods should be utilized to ensure maximum crop response to applied nutrient. These often include band placement options.

Nutrient Soil test interpretation for purposes of making nutrient recommendations is influenced by the mobility of the nutrient. With mobile nutrients (N, S, etc.), crop yield is proportional to the total quantity of nutrient present in the root zone (Figure 4). In contrast, yield response to immobile nutrients (P, K, etc.) is proportional to the concentration of nutrients near the root surface because these nutrients strongly interact with or are buffered by soil constituents. In general, crop response to concentrated zone placement (band vs. broadcast) is enhanced with nutrients exhibiting strong soil-nutrient interactions. Obviously, crop responses to specific nutrients either broadcast or band applied will depend on numerous site specific conditions. In addition, crop response to placement varies greatly between years, as temperature and moisture influence soil biological processes (mineralization, immobilization, etc.) important to N and S availability, and soil chemical processes (diffusion, adsorption, etc.) important to P and K supply.

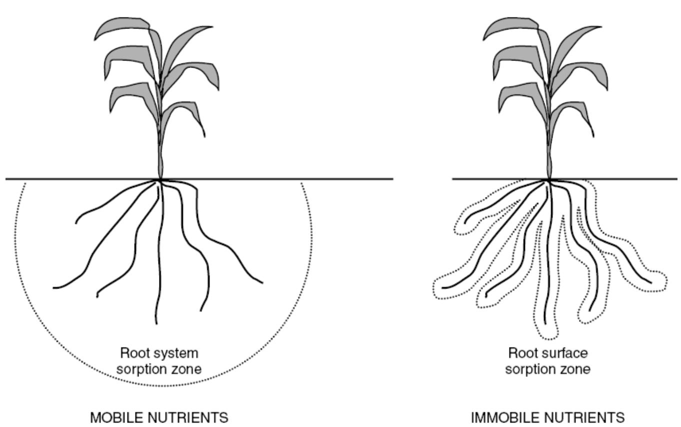

Figure 4. Difference in nutrient extraction zones between mobile and immobile nutrients

Soil and Tillage Systems Crop responses to nutrient placement are strongly influenced by cropping system, residue management, and numerous other factors that influence nutrient availability. Using N as an example, the principles inherent in crop response to N placement are best understood through evaluating the influence of N transformations on the fate of applied N. Depending on specific site characteristics (e.g. soil, crop, environment, management, etc.), crop responses to N placement depend on the proportional fate of applied N to N uptake and immobilization, and to a lesser extent volatilization, denitrification, and leaching (Figure 5).

For example, in reduced tillage systems significant N immobilization occurs depending on method of placement (Figure 6). Although many factors can influence the degree of response between broadcast, surface band, and subsurface band applied N, the surface residue quantity and characteristics (e.g., C:N ratio) greatly influence immobilization of applied N and subsequent crop response to N placement.

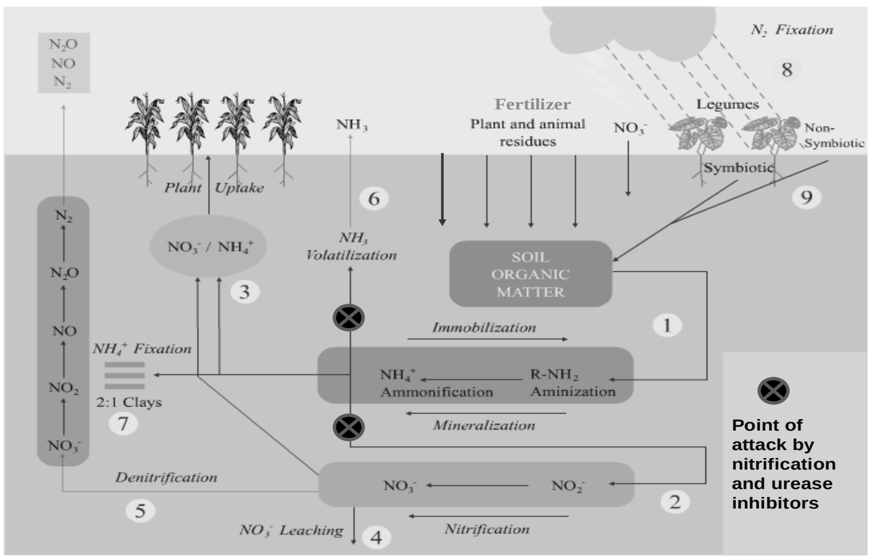

Figure 5. Nitrogen transformations in the soil N cycle that can influence crop response to N placement (Havlin et al, 2005).

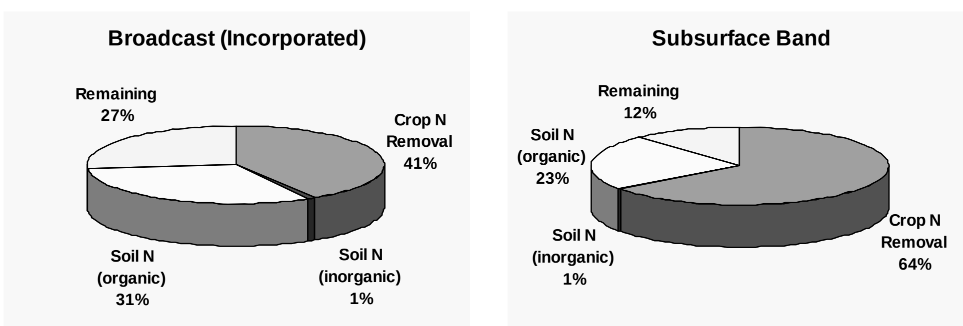

Figure 6. Influence of N placement on crop N removal and immobilization of applied N to corn (Maddux et al., 1991; N rate = 150 lbs N/a).

Although surface tillage effects on crop response to N rate and placement are influenced by both residue type and quantity, subsurface N placement generally reduces fertilizer N immobilization increasing fertilizer N recovery (Figure 7).

Crop responses to different N placement methods are also related to site characteristics that favor N volatilization. While NH_3 production in soil is a natural product of the N mineralization process (Figure 4), N volatilization losses of fertilizer N, while generally small, can be reduced

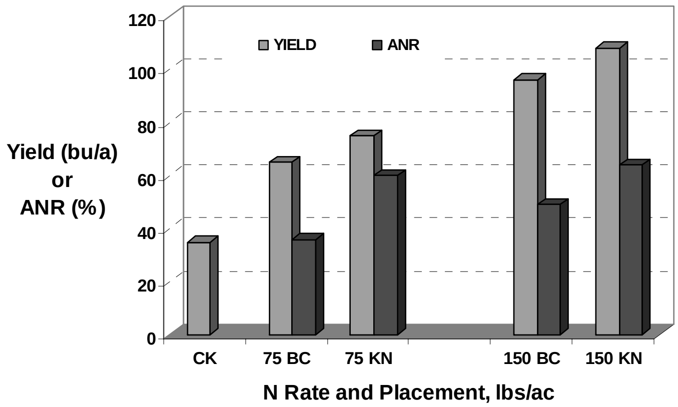

Figure 7. Effect of UAN placement on no-till corn yield and apparent N recovery (ANR) (Lamond et al., 1989)

through subsurface N placement. In addition, the effects of nitrification and urease inhibitors on reducing N losses and increasing fertilizer N recovery are well known.

Crop responses to P placement are strongly influenced by cropping system, soil P buffer capacity, and other factors that influence soil solution $H_2PO_4^-/HPO_4^{-2}$ concentration near absorbing root surfaces. Since the P requirement of most crops is greatest during the early growth period, it is essential to maintain sufficient P supply during this period. Therefore, the variation between locations in crop response to P placement can often be characterized by interactions between the crop, soil properties, and volume of soil fertilized with P (Figure 8). Generally, as P adsorption potential increases, crop response to band placement increases.

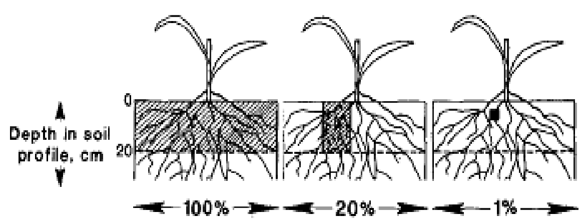

Figure 8. Illustration of the variation in soil volume fertilized with P (Kovar and Barber, 1989).

Review of P (and K) placement studies can be a frustrating exercise, where selected yield response studies show (1) no differences between placement methods, and (2) broadcast placement is better than surface or subsurface band

broadcast applied P (or K). Understanding the interactions between plant root morphology, soil conditions influencing early root growth, soil properties influencing P availability (including soil test P), and environmental conditions during early crop growth can help identify the most efficient P placement method (Figure 9).

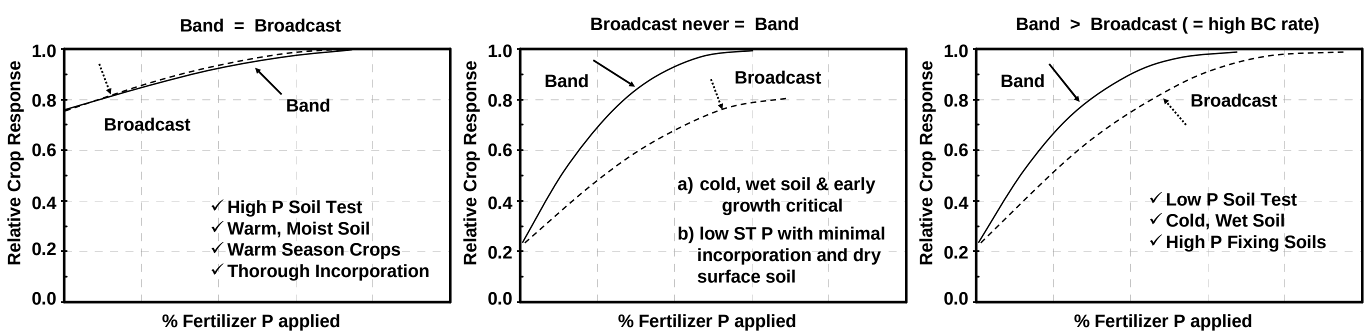

Figure 9. General differences in crop response to P placement methods and typical soil and environmental factors observed in each case (Fixen and Leikam, 1988).

Starter Applications As with other nutrient placement studies, review of starter placement responses can also be frustrating since responses can be inconsistent. Crop response to starter fertilizer depends on soil test levels, tillage system, and proximity to the seed. As with most band placement methods, the probability of a starter response decreases with increasing soil test level. With medium-high soil tests, yield response to starters is often related to cool, wet conditions in fine textured soils where early season nutrient diffusion may not meet early plant growth demand. In addition, starter responses are often more frequent in conservation tillage

systems (Table 1) where cool, wet soil conditions persist through early crop growth period and N mineralization is substantially reduced. Starter N can be especially important with N management programs that include split N applications later in the season.
If 20-30% or more of total N is preplant applied, crop response to starter N can be reduced.

Table 1. Starter effects on no-till corn yield (Gordon, 2001)

NPK Starter	With Seed	2 x 2	Dribble over Row	BC over Row
	----------------------------------	*bu/ac*	-----------------------------------	
0		159		
5-15-5	164	190	185	171
15-5-5	172	191	194	177
30-15-5	166	213	209	181
45-15-5	166	211	209	186
60-15-5	159	211	209	194
Average	**167**	**202**	**201**	**182**

Producers should be careful with starter materials that include N, K, or some micronutrients (e.g., B), applied in direct seed contact. Seedling injury can occur if starter fertilizers are applied in direct contact with corn seed at > 5-8 lbs/ac N+K. The lower of these rates should be used in coarse textured soils. Starter rates can be substantially increased if seed and fertilizer can be separated by 2+2 or another placement system on the planter.

Variable Nutrient Application Variable application of nutrients must be considered in any nutrient management program, especially under a relatively high nutrient cost and grain price environment. If nutrients are not variably applied, knowledge of the spatial distribution in soil test levels can still be utilized to identify the economic optimum uniform rate, which is often greater than that determined from commonly used composite soil sampling methods.

To illustrate, we use an 80-ac field where 40% of the field is <80% sufficient in plant available P (Table 2). If a composite sample were collected, the soil test P would be 21 ppm, which is above the 20 ppm critical level where no P would be recommended.

Table 2. An 80-ac field with a typical spatial distribution in soil test P.

Bray –P	Area	Sufficiency	P Rate
ppm	*Ac*	*%*	*lb P_2O_5/A*
0 - 5	10	50	70
5 - 10	23	78	50
10 - 15	14	90	30
15 - 20	7	94	10
> 20	26	98	0
Total/Average	**80**	**85**	**30**
Composite Sample Bray P = 21 ppm			**0**

However, using the weighted average of 15 ppm P, determined from the spatial distribution in soil test P, the P recommendation would be 30 lbs/ac (Table 2). Using predicted corn yield responses to P application (140 bu/ac yield goal) and the typical grain prices, fertilizer and other costs ($4.00/bu, $0.50/lb P_2O_5, $4/ac grid sampling, and $9/ac variable application), the estimated P rate, potential corn yield, and net return for each P management scenario is illustrated in Figure 10. Using variable rate application, the average P rate would be similar to that determined from the weighted average soil P levels (Table 2), however, the net return to variable P application was $25.45/ac compared to $12.79/acre using the weighted average P rate uniformly applied. The optimum uniformly applied P rate is determined by calculating the net return from increasing uniform P application rates until the maximum net return is identified, which was $20.52/ac (Figure 10). These data illustrate that variable P application maximized net return; however, if the producer still wanted to uniformly apply P, knowledge of the spatial distribution in soil test P resulted in a P recommendation that substantially increased net return compared to standard composite sampling methods.

P Management	Average Yield	P Rate
	bu/a	*lb P_2O_5/a*
No Applied P	118	0
Composite Sample	118	0
Weighted average Prec	130	30
Optimum Rate	139	58
Variable Rate	139	29 (ave.)

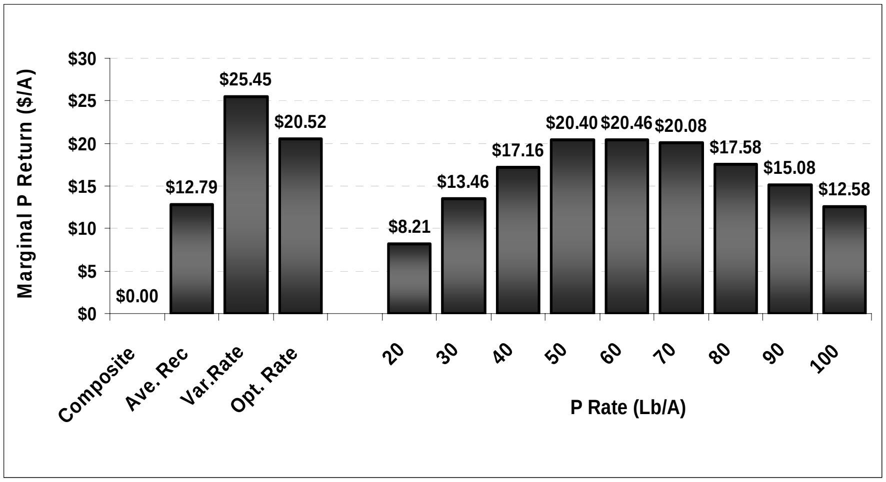

Figure 10. An example economic analysis of variable and uniform P application, where the uniform P rate is determined from the spatial distribution in soil test P (Table 2)

Summary   If a grower wants to know which nutrient placement method will result in the greatest return on investment, the answer provided by the dealer or consultant should be based on the best scientific evidence supporting the specific placement method, provided the supporting data were obtained from a location with similar site characteristics as the site in question. Therefore, the most appropriate recommendation(s) must be developed from considerations specific to crops and cropping systems, numerous soil and crop management factors, environmental parameters, and any other factor that influences crop response to nutrient placement. It is particularly important in assess the spatial variation in soil test properties influencing recommended nutrient rates to maximize net return.

References

Fixen, P.E., and D.F. Leikam. 1988. An overview of phosphorus placement. Proc. Great Plains Soil Fertility Workshop 2:37-51. Dept. of Agronomy, Kansas State Univ.

Gordon, W. 2001. Starter fertilizer application effects on reduced and no-tillage grain sorghum production. p 68–72. *In* Fertilizer Res. Prog. Rep. 885. Kansas State Univ., Manhattan, KS.

Havlin, J.L., J.D. Beaton, S.L. Tisdale, and W.L. Nelson. 2005. Soil Fertility and Nutrient Management. 7th Edition. Pearson Prentice Hall. Upper Saddle River, NJ.

Kovar J.L., and S.A. Barber.1989. Reasons for differences among soils in placement of phosphorus for maximum predicted uptake. Soil Sci. Soc. Amer. J. 53: 1733-1736.

Maddux, L.D., C. Raczkowski, D. Kissel, and P. Barnes. 1991. Broadcast and Subsurface-Banded Urea Nitrogen in Urea Ammonium Nitrate Applied to Corn. SSSAJ 55:264-267.

IFA, 2008. http://www.fertilizer.org/