WHERE DOES ROW-PLACED FERTILIZER FIT IN TODAY'S AGRICULTURE?

Richard Wolkowski - University of Wisconsin

Starter fertilizer has been a traditional component of row crop production in Midwest crop production systems. Typically, this material has been applied as a dry, granular blend, but the fluid materials have also become common. Wisconsin research has consistently demonstrated response to row-placed fertilizer. This response is generally attributed to (1) the cooler, wetter soil conditions that limit mineralization of nutrients from soil organic matter, (2) the slower metabolism of plants in the spring of the year, and (3) the reduced fixation of P and K compared to broadcast treatments. Research also has demonstrated response to starter in no-till and on compacted soils. The response in the later situations has been attributed to the K in the material. Recently, the use of starter appears to have diminished among growers for a number of reasons, including: (1) the expense a starter system adds to a planter; (2) the practicality of mounting and carrying starter attachments on large planters; (3) efficiency loss from tending the fertilizer; and, (4) the lower potential for yield response at high soil test P and K levels.

While starter is often positioned near the seed in a 2x2 placement, another option for starter placement — which has become more popular in the past decade — is the use of seed-placed or pop-up fertilizer. These are typically applied as fluid materials at low rates directly in the seed furrow. The obvious advantages to this method of placement are that more acres can be covered per tankful and that there is no need for special disks or other attachments to place the material. Disadvantages include potential seed injury from salts or ammonia (depending on carrier) and the questionable efficacy due to the low amount of actual plant nutrient applied. Some companies go so far as to claim that the plant will utilize seed-applied nutrients immediately, because they are applied in a "more available" form, with lower fixation by the soil.

This paper will discuss the research base for using starter fertilizer in the northern Corn Belt and offer suggestions with respect to conditions where its use is recommended.

It is likely that response to starter fertilizer will be field- and season-specific unless soil test levels are low. Bundy and Widen (1992) examined the relationship between tillage systems and planting dates on a responsive soil in southern Wisconsin for three seasons. Treatments included moldboard plowing and no-till, with four planting dates ranging between late April and late May using the same 95 RM hybrid. As expected, planting late reduced yield; but they found that yield response to starter tended to be stronger with the late planting compared to early planting. This was especially true in no-till, where response to starter was relatively greater than that found in the moldboard treatment. The exception to the response at late planting was with moldboard plowing and very early planting, where starter proved to be beneficial. Grain moisture also was lower where starter was used. Yield response data are summarized in Table 1.

Table 1. Response to starter fertilizer (10+25+25, $N+P_2O_5+K_2O$) as affected by tillage and planting date, average of three seasons, adapted from Bundy and Widen, 1992.

	Planting date			
Tillage	Late April	Early May	Mid May	Late May
	bu/a			
Moldboard	16	3	11	9
No-till	0	6	12	22

Numerous site factors are likely responsible for a response to starter fertilizer, especially where soil test P and K are high. Bundy and Andraski (1999) conducted an on-farm evaluation where cooperators applied their standard starter (or didn't) in replicated field-length strip plots over three years. A total of 100 site-years of data were collected. A number of factors were regressed against the "economic response" of 4.5 bu./acre to determine if they contributed to a yield response. These are shown in Table 2. Clearly, the greatest contributing factor to response was found with soil test K and the relative maturity of the hybrid. Sites having less than 140 ppm soil test K responded 56 percent of the time, whereas higher soil test K sites responded 34 percent of the time. Hybrids with an RM less than 100 days responded 33 percent of the time and hybrids with an RM greater than or equal to 100 days responded 53 percent of the time.

Table 2. Selected factors affecting the response to starter fertilizer from 100 on-farm trials, adapted from Bundy and Andraski, 1999.

Variable	Pr>F	Variable	Pr>F
Soil pH	0.99	Soil test P	0.63
Manure history	0.93	Nitrogen in starter	0.62
Phosphate in starter	0.91	Potash in starter	0.36
Soil organic matter	0.90	Soil yield potential	0.31
Surface residue	0.87	Planting date	0.29
Soil texture	0.77	Soil test K	0.05
Previous crop	0.64	RM	0.05

Bundy and Andraksi (1999) also developed an index that combined the Julian day planting date (days from January 1) with the hybrid's relative maturity (PDRM). For example, May 1 is Julian date 121, and if planted then with an RM 100 day hybrid the PDRM=221. PDRM values greater than 235, especially where soil test K is below 140 ppm, would be expected to have a relatively high response to starter fertilization. These authors recommend a complete starter material providing a minimum of 10+20+20 ($N+P_2O_5+K_2O$). Where soil tests are lower, some combination of starter and broadcast may be desirable to help build the soil test to optimum P and K levels.

The response to starter fertilizer has been shown to be greater and more frequently observed in no-till and other low-disturbance tillage systems when compared to conventional tillage, either as moldboard or chisel plowing. Some of this response may be due to reduced root growth in no-till, especially where traffic is not controlled. Research conducted by Kaspar, et al. (1991) clearly show root proliferation in a zone where starter was applied and reduced root development in the wheel track zone, when compared to the non-wheel tracked areas. Other studies that evaluated soil compaction show response to starter K fertilization possibly because of reduced aeration which affected K uptake (Wolkowski, 1989).

Recent research has compared fertilizer placement in both continuous corn and first-year corn following soybean where soil test levels are at the optimum P and K levels. This study contains chisel, strip-till, and no-till tillage systems, with no fertilizer or a PK fertilizer applied at a rate to match grain removal as broadcast or 2x2 (Wolkowski, 2004). Table 3 shows the three-year average response to these treatments. The relative response appeared to be greater in the first-year corn compared to the continuous corn. Early season plant samples showed considerably lower tissue K concentrations in first-year corn, possibly because of poorer K cycling in that situation. Considerable K would be leached from corn stover in continuous corn, essentially fertilizing the soil surface in that treatment. These data also show comparatively equal responses to broadcast fertilizer.

Fertilizer form — liquid or dry — is often a point of difference when selecting starter fertilizer materials. There are certain advantages to the liquid form, such as ease of handling, storage, nutrient analyses, etc. Liquid materials have limitations in analyses, especially K, which has been shown to be important in reduced tillage scenarios. Regardless of form, plants absorb individual ions from the soil. An acre-plow layer of a typical silt loam soil at field moisture capacity holds approximately 50,000 gallons of water. This should be more than adequate to dissolve a couple hundred pounds of dry fertilizer. Likewise, a few gallons of a liquid material are a “drop in the bucket” compared to the total soil water content.

Price is an obvious factor upon which many growers select fertilizer materials. It is important to determine the cost per pound of plant nutrients for certain specialty products. Regardless of form, fertilizer materials are expected to perform similarly when applied at equal rates of plant nutrients. Therefore, price should be an important consideration in today’s agricultural economy.

Salt injury is probably the most common concern with seed-placed fertilizer. The high concentration of soluble salts in the soil solution results in the flow of plant sap out of roots, causing the dehydration and death of plant tissue. The Salt Index provides a relative measure of the ability of a fertilizer material to increase the salt concentration of the soil solution. This index, developed by USDA researchers in the 1940s, compares the soil solution osmotic potential of a fertilizer with that of a standard (sodium nitrate). This term becomes more descriptive when expressed as the salt index per unit of plant food (salt index/analysis). These values clearly show why the rule-of-thumb seed-placed limit of 10 lb. $N+K_2O$/acre is based on the N and K content of the fertilizer. Examples of the salt index for some common fertilizer materials are given in Table 4. It should be realized that other factors, such as soil texture, soil water content, and crop sensitivity will greatly affect the potential for salt injury from seed-placement. Fertilizer should never be placed in the seed furrow with salt-sensitive crops such as soybean.

Table 3. Effect of rotation, tillage, and fertilizer placement on corn yield, Arlington, Wisconsin, 2001-2003 (three-year average).

Fertilizer	CC			SbC		
Placement	Chisel	Strip-till	No-till	Chisel	Strip-till	No-till
	-- bu./acre --					
None	169	173	147	192	184	177
Broadcast	176	168	163	194	209	200
2x2	186	172	164	195	201	197
Deep	--	172	--	--	208	--

Pr>F	2001	2002	2003
Rotation (R)	0.04	0.08	0.10
Tillage (T)	0.13	0.40	0.62
R*T	<0.01	0.43	0.93
Fertilizer (F)	0.04	<0.01	0.02
R*F	0.79	0.07	0.14
T*F	1.00	0.02	1.00
R*T*F	0.88	0.60	0.07

CC=Continuous corn; SbC=Corn after soybean.
Fertilizer rate=18+46+60 lb. $N+P_2O_5+K_2O$/acre.

Seed placement of urea or urea-containing materials is not recommended because of ammonia generation as the fertilizer hydrolyzes. Ammonia has a high affinity for water and will "burn" the tender tissue of germinating seedlings. Table 5 shows the first-year stand and yield results where granular urea was applied with the seed or in a 2x2 placement on a silt loam soil at Arlington in 1999. Control treatments of no row fertilizer and 10 lb./acre phosphate and potash applied with the seed or in the 2x2 placement were included in the study, but are not part of the ANOVA. These data show a stand reduction at the higher rates of seed-placed urea; however, the reduction was not as large as expected. This observation is likely the result of the fact that over 2.5 inches of rain was received in the 10 days after planting. The frequent precipitation maintained a high soil water content and held the level of free ammonia in check, although there was some stand loss. A significant yield reduction was observed where 30 lbs. N/acre as urea was applied with the seed. These data show a trend for a small response to P and K fertilizer in the 2x2 placement.

Table 4. Salt index for several common fertilizer materials. Source: Rader et al., 1943.

Material	Analysis	Salt Index	SI:unit
Ammonium Nitrate	34-0-0	104.7	3.1
Ammonium Sulfate	21-0-0	69.0	3.3
Urea	46-0-0	75.4	1.6
TSP	0-46-0	10.1	0.22
DAP	21-53-0	34.2	0.65
Muriate of Potash	0-0-60	116.3	1.93
Sulfate of Potash	0-0-50	46.1	0.92

SI: unit = Ratio of the salt index per analysis as percent plant nutrient.

Certain programs recommend the application of specific materials with the seed. Claims of increased nutrient availability over conventional methods often accompany recommendations that actually apply only a fraction of plant nutrient needs. Often, these claims are based on the materials used to make the products. When the price per pound of plant nutrient is calculated, the cost of some specialty materials is disproportionately high. Small amounts of plant nutrients applied with the seed should not be expected to perform similarly to conventional rates applied in the row on responsive soils. Table 5 shows the results of a three-year study at Arlington that compared liquid and dry materials with a seed placed program for corn. These data demonstrate the yield response to the appropriate rate of material regardless of its liquid or dry form. This rate was somewhat higher than crop removal, as a modest build-up in soil test was noted.

Seed-placement of starter fertilizer is a practice that presents the challenge of risk versus reward. The soil will control the availability of applied nutrients. Placement near the seed (2x2) should be equally efficient when compared to seed placement. Limited amounts of plant nutrients can be applied with the seed because of the potential for salt injury or toxicity problems. The long-term use of low-rate applications could result in lowering soil tests below optimum levels unless other applications are made. Compare the costs of various fertilizer materials and the expense of setting up planters to make fertilizer applications

Table 5. Effect of urea placement on the stand and yield of corn, Arlington, 1999.

Placement	Rate	Stand	Yield
	lb. N/acre	ppa x 1,000	bu./acre
Seed	7.5	28.6	182
	15.0	27.7	178
	30.0	24.0	169
2 x 2	7.5	30.7	187
	15.0	29.1	187
	30.0	28.5	184
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No starter	0	28.8	179
Seed PK	0	27.8	178
2 x 2 PK	0	28.2	184
Significance (Pr>F)			
Placement		0.01	0.05
Rate		0.01	0.35
P*R		0.30	0.64

All treatments except "no starter" received 10 lbs./acre of P_2O_5 and K_2O.
ANOVA includes urea-treated plots only. R. P. Wolkowski (1999), unpublished data.

Table 6. Corn yield and soil test as affected by starter fertilizer programs, Arlington, Wisconsin, 1981-1983. (three-year average).

Treatment	Yield	Soil test P	Soil test K
	bu./acre	------------ ppm -------------	
No starter	125	23	117
200 lbs./acre 6-24-24 dry	138	35	148
200 lbs./acre 6-24-24 liquid	141	37	150
3 gal./acre 9-18-9	128	22	122

Wolkowski and Kelling, 1985.

Summary

Nutrient management begins with soil testing and is followed by the efficient application of fertilizers or other materials. Banding starter fertilizer is historically recognized as the most efficient method of application because of the relatively greater recovery due to precision placement in the root zone and the lower fixation rate by the soil. This may become even more important in the future, considering that nutrient management plans may restrict broadcast application of P on sloping fields.

Corn producers should continue to consider starter fertilizer use, recognizing that economic responses will be affected by several site and management factors. Economic responses are more likely where full-season hybrids are planted later than usual (i.e., such that the sum of the Julian day and relative maturity are greater than 235). Responses are also more likely when soil test K levels are less than 140 ppm, and are most frequently seen in low-disturbance tillage systems such as strip-till and no-till. Fluid materials may provide more flexibility on larger planters, but may not supply the entire crop need of P and K, therefore some broadcast treatment, in addition to the starter, may be warranted.

The use of low analysis/low volume fluid programs is discouraged as these seldom supply significant amounts of nutrients and are typically more costly per pound of plant nutrient. Caution should be exercised when placing fertilizers directly with the seed. Do not exceed 10 lbs./acre of N+K_2O and avoid the use of urea-containing materials.

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