CROP INSIGHTS

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Use of Starter Fertilizers in Corn Production

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Summary

- Starter fertilizer is small amounts of plant nutrients placed in close proximity to the seed, usually at planting.
- Starter fertilizer benefits corn seedlings when growth of the nodal root system is slowed by weather, impeded by seedbed conditions, or damaged by pests or other factors.
- If early season stresses are sporadic in the field, starter fertilizer may help reduce uneven stand development and yield loss that often results from these conditions.
- Research results show that starter may provide the most benefit to growers using no-till or high-residue farming systems, growers in northern states, or those with coarse-textured (sand or silt) soils or other soils testing low in P.
  - In addition, growers who routinely plant very early in cold, wet soils may potentially benefit.
- Research also shows that starter fertilizer will not always increase corn grain yields, and would be particularly inconsistent when conventional tillage is used on moderately or well-drained soils testing high for P and K.
- Higher corn prices and changes in farming practices may create new roles for starter fertilizers; more research is needed to determine its potential applications.

Starter fertilizer in corn production has traditionally been recommended for fields with cool soil temperatures, including exceptionally early planted or no-till fields, those with high residue cover or fields in northern states. In cool soil conditions, starter fertilizer placed near the developing seed provides easily accessible nutrients until soil conditions improve and an adequate root system is established. Starter fertilizer has also been recommended for fields with low phosphorus levels, and research studies have proven the value of this practice. However, some growers seeking to exploit current grain price opportunities are evaluating whether starter fertilizer can play a more prominent role in increasing corn yields. This *Crop Insights* will discuss starter fertilizers, their traditional role in corn production, and whether starter may have a role beyond historical uses.

Starter Fertilizer Defined

Starter fertilizer is defined as small amounts of plant nutrients – nitrogen (N), phosphorus (P) and potassium (K) – placed in close proximity to the seed, usually at planting (Hergert and Wortmann, 2006). Placement can be directly below, to the side, or to the side and below the seed. Growers sometimes consider broadcast or liquid fertilizer application to the soil surface as "starter"; however, these should not be included because nutrient placement is positionally unavailable to early seedling growth. To be a "starter," nutrients must be strategically positioned to enhance early seedling vigor and development.

Figure 1. Case IH and John Deere tractors equipped with tanks for liquid starter application at planting.

Starter fertilizer placed in contact with the seed ("pop-up" fertilizer) is another option, but its use requires a great deal of caution to avoid possible germination and seedling injury. The amount of pop-up that can safely be applied is limited, and depends on the fertilizer used and soil properties. For example, starter fertilizer containing ammonium thiosulfate should not be placed in contact with the seed (Hergert and Wortmann, 2006).

A starter fertilizer is usually composed of two or more nutrients. Under most situations, a combination of nitrogen and phosphorus constitutes an effective starter material. Liquid 10-34-0 and dry 18-46-0 are common starter fertilizer materials. Liquid 7-21-7 and dry 8-32-16 are also commonly used. Other fertilizer formulations may be used as starters; for example, the addition of zinc and/or sulfur may be warranted in sandy, low organic matter soils.

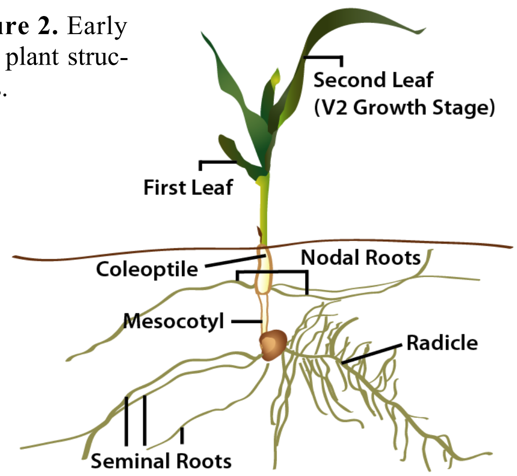
To fully understand the role of starter fertilizer in providing basic nutrition to corn seedlings, it is useful to review the physiology of early corn root development.

Early Corn Root Development

After corn seeds imbibe enough water for germination, the first root structure to emerge is the radical, which is soon followed by the lateral seminal roots (Figure 2). The seminal root system does not take up substantial quantities of nutrients;

instead, the young seedling relies primarily on the stored nutrient reserves of the seed at this stage of development.

Figure 2. Early corn plant structures.



Soon after emergence (VE) the young corn seedling will begin to develop its nodal root system, the primary roots for water and nutrient uptake of the plant (Figure 2). If normal development of the nodal roots is impeded and the endosperm reserves of the seed become depleted, the plant will lack the basic nutrients needed for optimum growth. When nodal roots are impeded, above-ground symptoms may appear as less vigorous or less green plants.

By the V2 stage (2 leaf collars visible) it is important for corn plants to be actively taking up nutrients such as N (Figure 2). Although these nutrients are needed in very limited quantities, they are none the less essential in the plant's ability to run its newly developing photosynthetic machinery.

Stresses May Impede Nodal Roots

Stresses that impede nodal root development may be caused by living (biotic) organisms such as insects or diseases or by non-living (abiotic) physical or chemical factors such as soil obstructions, soil moisture conditions, cool temperatures, or fertilizer placement. Stresses may be continuous in the field, or may occur sporadically in microenvironments throughout the field.

Continuous or uniform stresses that affect plants equally often include cold or wet soil conditions or below optimum air temperatures. Although detrimental to crop growth and sometimes yield, these stresses are generally less damaging than sporadic stresses that affect one plant and not its neighbors. This is because individually affected plants are likely to fall behind in physiological growth stages if conditions remain unfavorable.

Once a plant begins to fall behind by two or more growth stages, it becomes increasingly difficult for the plant to catch up. This is commonly thought to be a consequence of shading by its competing neighbors. Shading slows the plant's growth rate, further reducing root elongation and nutrient uptake. Thus, the problem of competing for limited resources is compounded, likely for the remainder of the plant's life cycle.

Sporadic or variable stresses in a field can be more detrimental to grain yield than continuous stresses. Sporadic stresses include: uneven residue distribution, dry or cloddy soils, wet spots, diagonal anhydrous ammonia bands, fertilizer salt injury, wheel traffic compaction, seed furrow (sidewall) compaction, insect or herbicide damage to roots, and soilborne diseases.

Uneven stands have been reported to suffer corn grain yield reductions from six to as much as 23 percent depending on the severity (Nielsen, 2010; Nafziger, et al., 1991). **This yield loss could be significantly reduced by starter fertilizer applications in cases where the primary cause of uneven stands is the inability of the young nodal root system to access sufficient soil nutrients**.

Figure 3. Uneven stand due to wet soil conditions. Note that variable soil areas are affecting some plants more than others.

Research on Corn Yield Response to Starter

Starter fertilizer applications to corn have been well researched and documented. The scientific literature shows numerous cases where starter has produced positive, meager and no corn grain yield increases. This array of results means that positive grain yield responses are likely related to both environmental and cultural interactions. Several important studies are discussed below.

Starter Research Results by Geography and Type of Nutrients in Starter

- Researchers in Minnesota found a corn grain yield response to nitrogen (N), phosphorus (P) and potassium (K) starter fertilizer regardless of tillage practices. (Vetsch and Randall, 2002). These and other research results suggest that the primary geographic region that might consistently and positively respond to starter fertilizer are areas of the northern Corn Belt.

- In the central and northern Corn Belt states of Illinois, Wisconsin and Iowa, researchers found similar results when N, P, and K starter fertilizers were used. However, grain yield increases were much more consistent in soils that were low testing for P, poorly drained, or managed with no-till or reduced tillage (Wolkowski, 2000; Mallarino et al., 1999; Randall and Hoeft, 1988).
- Researchers in Indiana found a yield increase to starter P and K at only one site under conventional tillage (spring chisel plow) but found consistent yield increases if corn was managed under a no-tillage production system (Mengel et al., 1988).

Because starter fertilizer experiments are often conducted using N, P, and K fertilizers it is not always exactly clear which nutrient provided the yield increase; however:

- Researchers in Iowa conducted experiments in no-till high testing P soils with both P and N starter fertilizers and found that N was largely responsible for the yield increases (Bermudez and Mallarino, 2003).
- Other research supports responses to N-only starter fertilizer, most typically if cool wet soils are elevated with a chisel plow or strip tillage (Touchton and Karim, 1986).

Conclusions: It can further be concluded that if growers in the central Corn Belt states are using high rates of broadcast fertilizer (P and K) in a build and maintain fertilizer program, starter P and K yield responses would be even less consistent and unlikely, especially if conventional tillage practices are being utilized (Kaiser et al., 2005).

Research Results by Soil Type

Consistent grain yield responses to starter fertilizers may also be expected on soils that have low soil organic matter or soils that have coarse (sandy) soil surface textures. Many soils formed from Mississippi River alluvium that stretch from portions of central Minnesota to the Gulf of Mexico fit this description. Several studies report results by soil type:

- Researchers in Louisiana noted early P deficiencies on silt loam and sandy loam soils that have an organic matter content of less than 1 percent (Mascagni et al., 1996; Mascagni et al., 2007).
  - These researchers found that starter N and P applications significantly increased corn grain yields in five out of 15 environments (and numerically increased yield in 12 of 15 environments) even when extractable soil P levels were high on these soils (Figure 4).
  - Moreover, the average grain yield response was 12.5 bushels an acre when averaged across all years and locations, although yields were not always significant at the 0.05 probability level.
  - In addition, it was concluded that the observed grain yield responses were more likely from the P in the starter fertilizer and the largest, most consistent grain yield responses were on the coarsest textured (sandiest) soils (Mascagni et al., 2007).

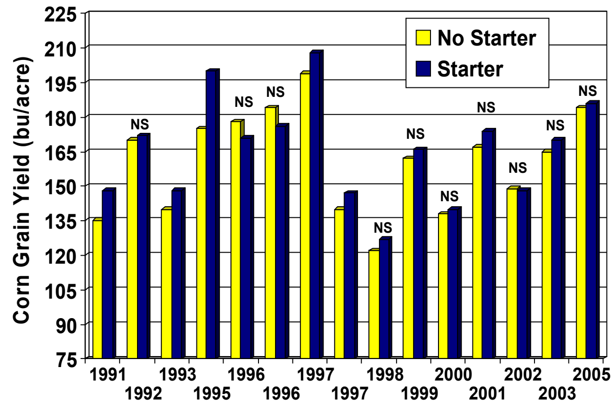


Figure 4. Influence of starter fertilizer on corn yield on Mississippi River alluvial sandy loam/silt soils at the NE Research Station at St. Joseph, Louisiana. Mascagni et al., 2007. NS = Non-significant at the .05 probability level.

- Congruent research in other southern states on sandy loam soils when P and K levels were high showed consistent grain yield responses from starter fertilizers. Moreover, grain yields were significantly higher with N starter alone; however, they were slightly higher in other years when P and K starter was added (Touchton and Karim, 1986).
- Conversely, research in North Carolina showed no yield increase to P and N starter fertilizer when compared to just N starter fertilizer in sandy soils when P levels were high (Chaill et al., 2007).

Conclusions: It seems apparent from the reviewed literature that starter fertilizers of N, P and K in sandy loam and coarser-textured soils might be warranted even if P and K levels are high. However, it is impossible to tell if N, P and K are needed or just N, due to conflicting findings in these environments.

Hybrid Responses to Starter Fertilizer

Kansas State researchers studied five hybrids ranging in maturity from 103 to 113 RM, with and without starter fertilizer (N and P) in a no-tillage production system (Gordon, 1997). This Kansas study found that starter fertilizer significantly increased early season growth, N and P uptake at V6, and N and P concentration in the ear leaf. However, no hybrid by starter interaction was found (i.e., all hybrids responded similarly to starter application). The study also measured growing degree units (GDUs) to pollination. All hybrids required less heat units to begin pollination when starter fertilizer was used (Table 1). This is a key finding for dryland corn production in Kansas, where yield is often limited by late season drought stress. Furthermore, earlier pollination under these conditions can lengthen the grain filling period and increase corn grain yield potential.

Table 1. Starter fertilizer effect on grain yield and GDUs to pollination of corn hybrids. (Adapted from Gordon, 1997.)

Hybrid	Starter	Grain Yield (bu/acre)	GDUs to Pollination
ICI® brand 8599	With Without	150 148	1151 1205
Pioneer® brand 3563	With Without	174 171	1187 1223
DeKalb® brand 591	With Without	176* 165	1191* 1304
DeKalb® brand 636	With Without	175* 161	1235* 1379
Pioneer® brand 3346	With Without	188* 174	1221* 1386
Hybrid x Starter LSD(0.05)		9	71

*Significant at the 0.05 probability level.

Banded Applications More Efficient

Application of P as a starter fertilizer is usually more efficient than broadcast applications, especially when inherent soil P levels are very low or for calcareous high pH soils (Shapiro et al, 2003). For example, recommended P rates can be reduced by 1/2 when applied as a banded starter fertilizer compared to broadcast application (Table 2). This is because banded starter applications result in less soil immobilization and more crop available P than broadcast applications, especially for high pH soils with low P levels. Use of a band-applied P starter is an especially appealing alternative to broadcast application when P based fertilizers are extremely expensive.

Table 2. Phosphorus fertilizer recommendations [1].

Soil P Level (ppm P)		Relative Level	Amount of P to Apply (P_2O_5)	
Bray-1 or Mehlich-3 [2]	Olsen P [3]		Broad-cast [4]	Band [5]
0 - 5	0 - 3	Very Low	80	40
6 - 15	4 - 10	Low	40	20
16 - 24	11 - 16	Medium	0	0
25 - 30	17 - 20	High	0	0
>30	>20	Very High	0	0

[1] Shapiro et al. 2003.

[2] Bray P-1 for acid and neutral soils, Mehlich-3 for all soils.

[3] Olsen P for calcareous soils.

[4] This equation provides an alternative to using table values:

If Bray-P < 25 ppm: P rate (lb P_2O_5/acre) = (25-Bray-P) x 4

If Bray-P > 25 ppm: P rate (lb P_2O_5/acre) = 0

Bray-P = Bray-1 phosphorus (ppm) in 0-8 inch depth

[5] Applied in band preplant or beside the row at planting.

Avoiding Salt Injury from Starter Fertilizers

The rate at which a starter fertilizer can be applied depends upon the salt content or index of the fertilizer, proximity of starter to the seed, and soil texture (Hergert and Wortmann, 2006). Salt index is a function of the sum of the nitrogen, potassium and sulfur amounts present in the fertilizer. Salt indexes of common starter fertilizers are shown in Table 3.

Table 3. Salt index comparisons for commonly used starter fertilizer products, expressed as pounds of salt effect per gallon and relative to 10-34-0.

Product	Salt Index, lb/gal	Value Relative to 10-34-0
Ammonium polyphosphate 10-34-0	2.28	1
7-21-7	3.04	1.33
Urea ammonium nitrate 28-0-0	6.75	2.96
Urea ammonium nitrate 32-0-0	7.78	3.41
Ammonium thiosulfate 12-0-0-26	30.9	13.55

From J.J. Mortvedt, Calculating Salt Index.

Products like ammonium polyphosphate (10-34-0) have a low salt index value (2.28 lb/gal) while ammonium thiosulfate 12-0-0-26 possesses a high salt index value (30.9 lb/gal). The limits for application rates of 10-34-0 to help avoid salt injury as a function of fertilizer placement and soil texture are shown in Table 4. Salt damage is most pronounced when soil moisture is low, so adequate soil moisture at planting or rainfall soon after help minimize salt injury. To diminish the probability of salt injury, avoid over-applying nitrogen, potassium or sulfur fertilizers close to the seed.

Table 4. Amount/acre of 10-34-0 [6] that can be safely applied for corn [7] in 30-inch rows [8] as influenced by distance from the seed and soil texture (Hergert and Wortmann, 2006.)

Placement	Sandy Soils	Non-Sandy Soils
	10-34-0 (gal/acre) [6]	
With the seed (pop-up)	5	5
1/4 to 1/2 inch from the seed	10	10
1 inch from the seed	20	40
2 inches or more from seed	20+	40+

[6] Determine safe application rates for other fertilizers by dividing the value in Table 4 by the "Value Relative to 10-34-0" in Table 3.

[7] The safe application rate for soybeans is 1/2 of these values.

[8] For row-widths narrower than 30 inches, the application rate may be increased. Multiply values by 1.5 for 20-inch rows, 1.36 for 22-inch rows, and 2.0 for 15-inch rows.

Conclusions

Corn grain yield increases from starter fertilizer applications are most likely:

- In northern portions of the Corn Belt, regardless of tillage practices
- When cultural practices such as no-till or minimum tillage are utilized
- On coarse textured and or low organic matter soils
- On poorly drained or cold soils
- On low testing P and K soils
- When nodal root systems are severally impeded by abiotic or biotic stresses
- When soils pH is unusually high or low
- When substantial drought stress is likely

Higher corn prices and changes in farming practices (e.g., earlier planting) may create new roles for starter fertilizers beyond their traditional applications. One such role may be as insurance against prolonged, unfavorable weather conditions occurring soon after planting. Growers and agronomists are encouraged to continue testing starter fertilizer in a variety of field situations to further determine when and where these treatments may be most responsive.

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