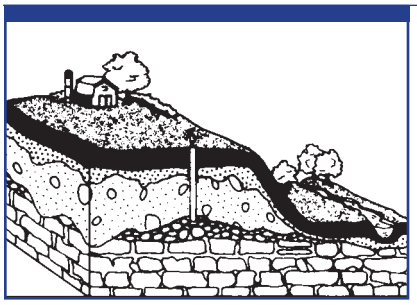

Soil Facts

Starter Phosphorus Fertilizer and Additives in NC Soils: Use, Placement, and Plant Response

Phosphorus (P) is the second most important nutrient in crop production but is often found in relatively low amounts in native soils. Decades of fertilizer application have led to P enrichment of most NC agricultural soils. Excess soil P that leaves agricultural fields via runoff and drainage can cause algal blooms in water resources that lead to impaired drinking water quality and can limit recreational activities. Maintaining adequate soil P levels for crop growth can reduce P runoff, save money, and protect the environment.

Soil testing is the only way to determine the plant-available P in the soil. In fiscal year 2008, the Agronomic Division of the NC Department of Agriculture and Consumer Services (NCDA&CS) found that over 45 percent of statewide soil samples tested very high in soil test P (Table 1). Soil test P levels are reported as indices by NCDA&CS after analysis using Mehlich-3 soil test extractant. The scale ranges from 0 to greater than 100, as noted in Table 1.

Table 1. Soil test phosphorus levels in NC soil samples tested by the NCDA&CS, 2008 report

Soil Test P Level	Soil Test P Index	Percent of NC Soil Samples (statewide)
Very high*	>100	45%
High*	51 – 100	29%
Medium	26 – 50	16%
Low	11 – 25	6%
Very low	0 – 10	4%

***No yield response is expected for soils testing as high and very high based on NC fertilizer recommendations.**

Starter P fertilizers have traditionally been used in crop production on soils of various soil test P levels. Recent data show that starter P fertilizer is not necessary on mineral soils that test high or very high in soil test P in North Carolina. Not applying P fertilizer on soils with high or very high soil test P would save producers money, reduce soil test P levels in time, and reduce environmental consequences from agricultural fields.

Using a Starter P Fertilizer

Traditionally, starter P fertilizer is used in crop production in North Carolina. Often the rate of starter P is not based on soil test P recommendations.

Fifty-one trials in North Carolina's coastal plain, piedmont, and mountains investigated whether using starter P fertilizer would affect the growth of corn and cotton on soils having very high soil test P and some having high soil test P. Treatments were starter nitrogen (N) and diammonium phosphate, and starter N only. Significant treatment differences were not observed for corn or cotton yields (Figure 1, page 2) (Cahill et al., 2008). The use of only starter N is typically more cost effective than using both N and P starter fertilizers. Starter P fertilizer generally was not effective on mineral soils in NC fields with high or very high soil test P values.

P Fertilizer Enhancers

On soils that are likely to benefit from starter P application (soils with very low, low, and medium soil test P or very high or low soil pH), P fixation can be a problem. Applied P fertilizer can be rapidly fixed in soils, resulting in substantial amounts of the applied P becoming unavailable to plants. Fertilizer additives have been developed with the goal of reducing phosphate fixation in soils. These products do not supply nutrients and cannot be evaluated based on nutrient content. Examples include water soluble humic and fulvic acid products, and maleic itaconic copolymer

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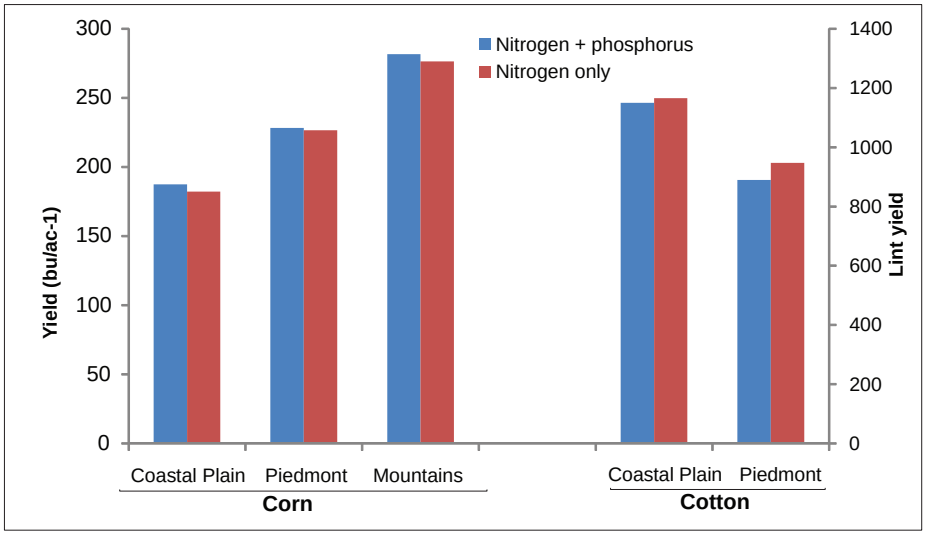


Figure 1. Mean corn (bu/ac) and cotton (lint) yields by region on soils with very high soil test P. Adding P to the starter fertilizer did not significantly increase yields in any NC region.

for P fertilizer. Manufacturers state that these products may increase soil cation exchange capacity and limit reactions that reduce P availability.

Calculations by NC State University Soil Science faculty found that the increase in cation exchange capacity when using a humic acid or a polymer product is relatively small, only occurs in the fertilizer band zone, and will not affect subsequent crops (Crozier et al., 2009). Applying humic acid products at manufacturers' recommended rates is also unlikely to change soil humate concentration.

Management practices, such as crop rotation and the use of cover crops and manures, can increase soil moisture-holding capacity, soil organic matter concentration, and cation exchange capacity (CEC). Applying lime can also increase CEC. Producers should compare these practices to the use of P enhancer products.

AVAIL Fertilizer Enhancer

One specific maleic itaconic copolymer product being marketed throughout the United States is AVAIL® (Specialty Fertilizer Products, Belton, MO), a granular P fertilizer enhancer. According to the manufacturer, AVAIL is designed to reduce P fixation of applied P fertilizers by surrounding the fertilizer with a water-soluble 'shield' that blocks the bonds of attraction between P and chemical elements that tie-up P in soil (typically calcium, magnesium, iron, or aluminum, or a combination of these elements). The manufacturer does not link these claims to soils of any particular soil test P level.

More than 20 trials were conducted throughout North Carolina from 2007 to 2009 with the AVAIL enhancer. Using starter P fertilizer sources with and without AVAIL were compared, at various rates and with different application methods. These studies were conducted primarily on corn sites, but also included cotton and soybean sites. Soils ranged from a very poorly drained, fine sandy loam to a well-drained silt loam. Soil test P on test sites ranged from low to very high. The conclusions from the 20 trials suggest that starter P fertilizer plus AVAIL enhancer does not significantly increase corn grain or cotton lint yields over starter P fertilizer alone (Ambrose, 2009a; Braswell, 2008; Cahill et al., 2009a). When comparing application methods, AVAIL did not increase soybean yields regardless of method applied, and response to rates was generally not seen for each crop.

An example of the many trials in which we tested AVAIL was a 2-year field trial with fertilizer treatments including AVAIL on low and medium soil test P soils in the NC mountains. Overall, corn yield, early season plant color, height, and tissue N or P did not respond to diammonium phosphate treated with AVAIL differently than untreated diammonium phosphate (Cahill et al., 2009b). Yield did not respond to increasing P rates (Figure 2), indicating that site soils were able to supply adequate P to achieve maximum yields.

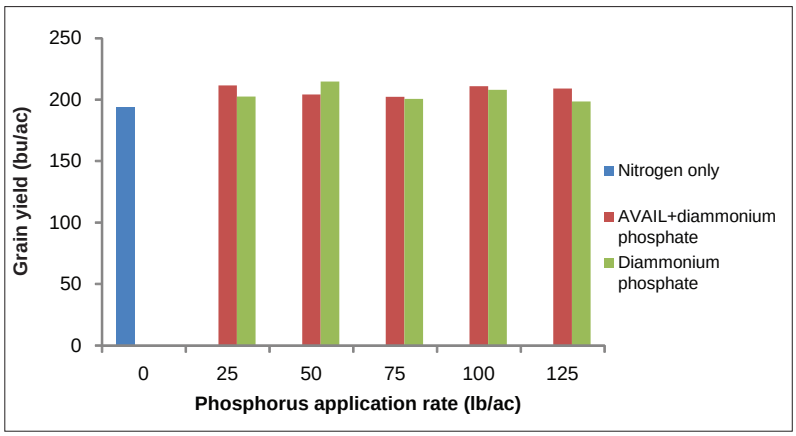


Figure 2. Mean corn grain yields (bu/ac) in the NC mountains on soils of low and medium soil test P. No significant yield increases were detected due to additions of P, either with or without AVAIL, in the starter fertilizer.

Factors that Influence Plant Response to Starter Fertilizers

Other factors may influence corn response to starter fertilizers, including the tillage method, soil type, soil fertility status, and yield potential. Conditions that limit growth or yield may also affect plant responses to starter fertilizers. Poor stands, insect or nematode damage, or drought can negate the effects of starter fertilizers.

Starter P Fertilizer Placement

We also investigated whether fertilizer placement affected plant growth. Several placement options exist for starter P fertilizer.

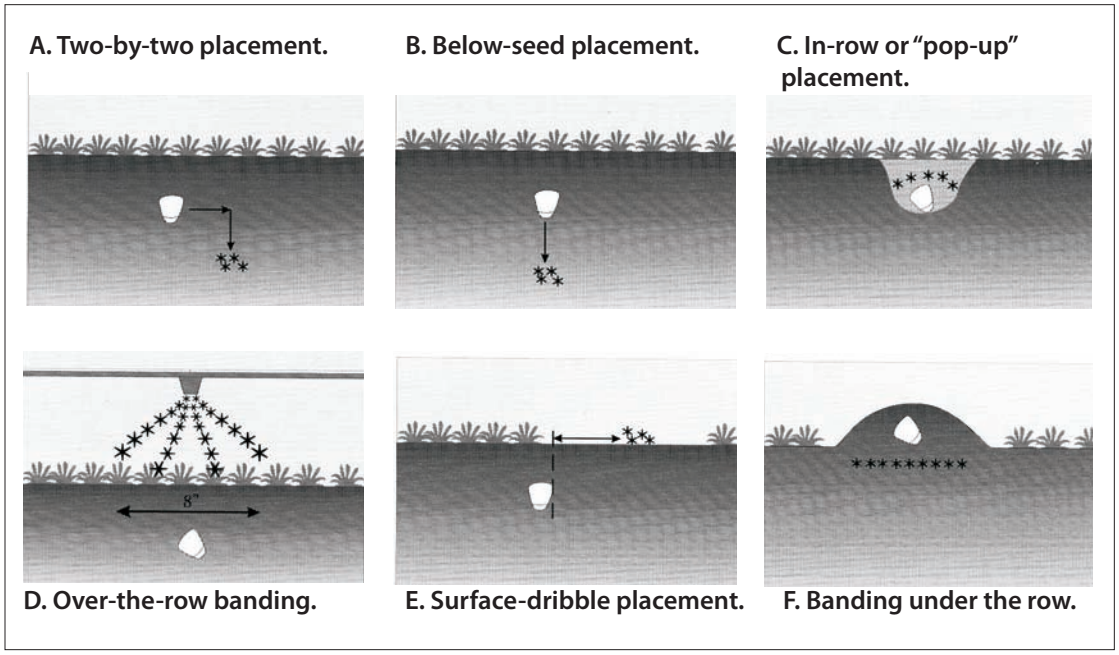
Two-by-two placement is the most common starter placement: 2 inches to the side of and 2 inches below the corn kernel at planting (Figure 3A). This precision placement method, called 2 × 2 placement, requires specialized equipment, usually consisting of reverse knives, double-disk openers, or coulters with drop tubing behind them. Each equipment type has advantages depending on the tillage system used (such as no-till or conventional). All 2 × 2 placement units should be mounted in a manner that will allow them to "float" with the planter. Planter bar and row unit spacers often make it difficult to install additional fertilizer attachments. That's why many users place fertilizer attachments on forward-mounted tool bars. Forward mounting of starter fertilizer equipment, however, makes placement less precise on rough or rolling ground. These mechanical constraints and the expense of application equipment for placement have prompted researchers and producers to try the alternative placement methods described next.

Below-seed placement (Figure 3B) is suited for in-row subsoiling units. When liquid fertilizer materials are used, a drop nozzle or stainless-steel tube can be attached to the subsoil shank with adjustable locking collars that allow fixed placement at any depth below the seed. With application, care should be taken to prevent the liquid fertilizers from adhering to the subsoiler shank. When this occurs, the liquid starter drips down to the subsoiler shoes and is unavailable for early plant growth. Splatter shields can be welded at specified depths on the subsoiler, or a K-3 or K-5 flood nozzle can be mounted on the end of the drop nozzle with a 45-degree elbow directing the nozzle spray away from the subsoiler shank. Either method will prevent the fluid from dripping down to the subsoiler shoe. When granular fertilizers are used, materials should be allowed to fall freely into the subsoil rack from a height 6 inches above the soil surface. Soil movement prevents granular materials from dropping all the way down to the subsoiler shoe. Below-seed placement is not as precise as a "floating" 2 × 2 placement or any surface placement because of draft bar movement.

In-furrow placement (Figure 3C) of fertilizer with the seed requires simple equipment but may result in fertilizer injury. Fertilizers applied with this technique are commonly referred to as "pop-up" fertilizers. Pop-up fertilization in North Carolina should be applied at lower rates than 2 × 2 placement to reduce salt damage risk. However, some growers working with organic soils have used 5 gallons of 10-34-0 fertilizer per acre placed in the furrow, and researchers in Tennessee have found that little injury occurs when small amounts of pop-up fertilizers are used in clay soils.

Surface banding over the row (Figure 3D) may be more effective on sandy soils than on clay soils. Placement can be accomplished with conventional banding equipment. Starter fertilizer solutions may be sprayed over the seed furrow with nozzles placed behind the press wheel. Band widths of 6 to 12 inches can be obtained with nozzle height adjustments. This method requires less fertilizer than broadcast and places nutrients near roots where plants can use them more readily.

Figure 3. Placement alternatives for corn starter fertilizer.



Surface dribble (Figure 3E) may also be most effective on sandy soils. It can be set up with conventional banding equipment oriented to deliver a stream of starter fertilizer to be offset 2 inches on one or both sides of the seed furrow. Most often, an appropriately sized orifice is used to meter the starter fertilizer. If a fan nozzle is used, it must be turned parallel to the seed furrow direction.

Banding under the row (Figure 3F) is done with a T-shaped PVC manifold with orifices extending along a specified band width and mounted on a disk bedder. Precision with this method of starter fertilizer placement depends on the bedder's action. Abrasive action of soil during bedding may reduce the life of the PVC manifold. Bands should be placed at least 2 inches away from the seed to prevent damage.

Broadcast is a uniform distribution of fertilizer or lime on the soil surface. Nutrients may be placed in the field as topdressing or incorporated with a moldboard plow, chisel plow, or by disking. Although this application is easy to apply and does not require expensive equipment, it can result in N losses and more fertilizer available for weeds, and it requires water to move the N to plant roots.

Plant Response to Placement Methods

Plant growth and nutrient uptake can be influenced by placement method (Figures 4 and 5). In general, placing the fertilizer close to the seed gives the greatest plant response. It is also important to ensure that application equipment is aligned uniformly so that starter fertilizers are placed the same distance from each row. Large plant growth variations between rows may be observed with placements differing by only ½-inch.

Final corn grain yields can also be affected by starter placement. In Florida, the 2 × 2 and surface dribble methods appeared to be superior to other placement methods (Table 2) (Wright, 1991). In Illinois, less fertilizer was needed from 2 × 2 banded placement than from broadcast to obtain a specific corn yield on soils with low soil test P (Welch et al., 1966). When the soil had medium soil test P, no corn yield differences were observed between 2 × 2 and broadcast placement.

Table 2. Effect of Starter Fertilizer Placement Methods on Corn Grain Yields in Florida

Placement	Year 1984 (bushels/acre)	Year 1985 (bushels/acre)	Year 1986 (bushels/acre)	3-Year Average
Check	142	169	130	147
In-furrow	107	173	—	—
2 x 2	172	210[1]	163	182
Surface dribble	170	186	168	175
2 inches below	122	178	162	154
5 inches below	137	177	152	155
7 inches below	139	189	162	163

[1]Planted 4 days after other test. Comparable check = 186 bushels/acre.

Source: D. Wright, 1991. In Starter fertilizers for Crops in the Southeast, Technical Bulletin 1991-1. Atlanta, GA: PPI, FAR.

Results from a 1-year soybean study (2009) in Bertie County (Figure 6A) showed no clear advantage from fertilizer placement, form, or source (Dunphy et al., 2009b). Most treatments did not yield as high as the check plots where no P was applied. Results at the second location in the study, in Forsyth County (Figure 6B), indicated broadcast treatments yielded higher than in-furrow, regardless of fertilizer source (Dunphy et al., 2009a). These data were part of a 1-year study, and provide an example of variable results between sites and treatments.

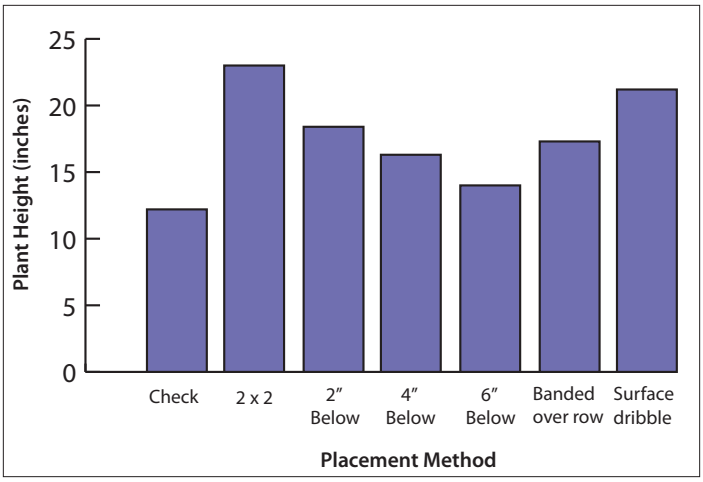


Figure 4. Effect of starter placement on corn plant height.

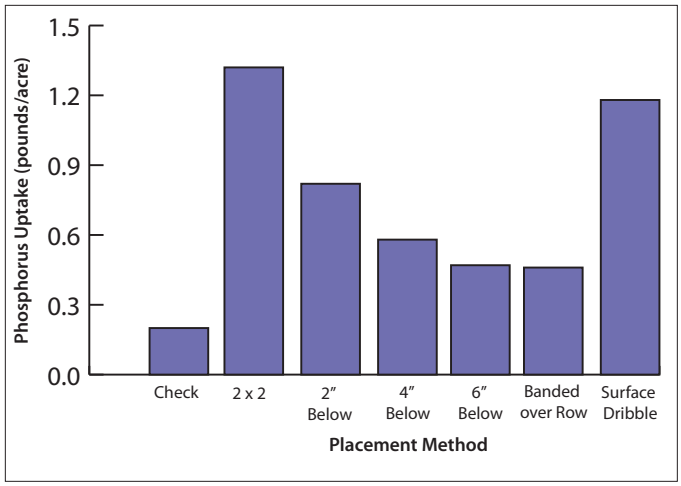


Figure 5. Effect of starter placement on P uptake.

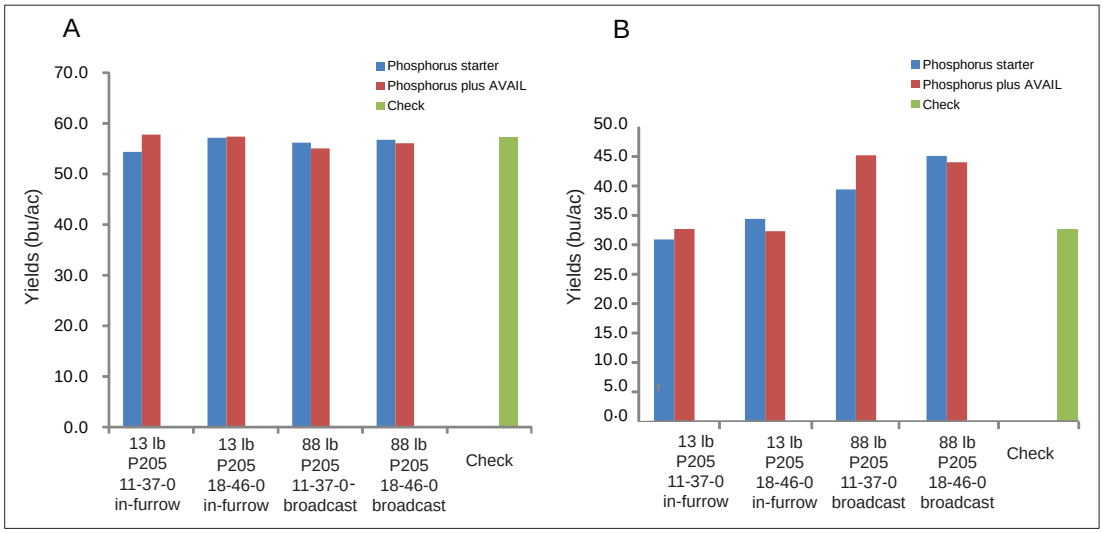


Figure 6. Soybean yields (bu/ac) from a 1-year study in (A) Bertie County in the NC coastal plains and (B) Forsyth County in the NC piedmont are influenced by P rate and placement (Dunphy, Ambrose, and Buffaloe, 2009; Dunphy, Rhodes, and Buffaloe, 2009).

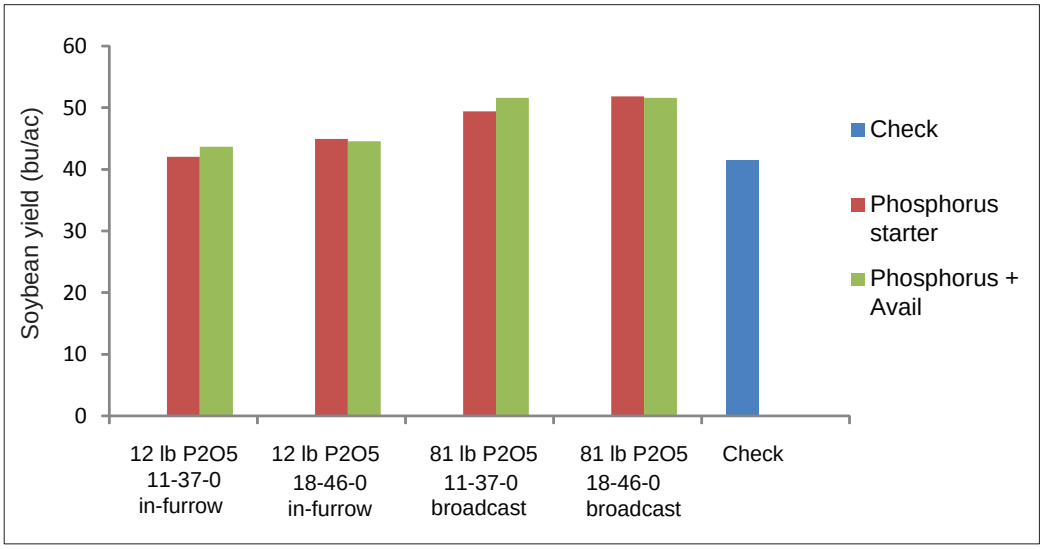


Figure 7. Soybean yields (bu/ac) in Beaufort County on a fine sandy loam soil are influenced by P rate and placement (Ambrose, 2009).

Additional on-farm evaluations of fertilizer sources, with and without AVAIL, were conducted on soybeans grown on a Craven fine sandy loam soil in Beaufort County in 2009. The soil test P index at the study site was 25 (low). All treatments had greater yields than the untreated check where no P was applied, confirming the responsiveness of the site to P application (Ambrose, 2009b). As Figure 7 shows, broadcast application at a high P rate produced higher yields than in-furrow at a lower P rate. AVAIL did not increase soybean yields over starter P alone, regardless of application method or sources.

P fertilizer placement, source, and form should be based on specific farm management systems with consideration given to the soil characteristics of your farm.

Summary

Eliminating starter P fertilizer applications on high and very high soil test P soils is both financially beneficial to producers and environmentally beneficial to our water resources. Recent research across the state on various soil types with different soil test P levels found few differences among plots fertilized with starter P and N fertilizer sources compared

with N only sources. P fertilizer does not appear to be necessary on mineral soils in North Carolina testing high or very high in soil test P. Starter P still should be used on organic soils that test high. In addition, multiple field studies across our state, on many different soil types, soil test P levels, and crops show that the use of AVAIL fertilizer enhancer with P rarely increased yields.

Starter P fertilizers can be applied several ways, depending on producer preference and the mechanical equipment. On sites with relatively low soil test P, a 2 × 2 placement is recommended to reduce P fixation and provide more P to the crop.

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