Science Societies

Can banding reduce phosphorus rates and environmental losses?

By Susan Winsor

April 29, 2022

Photo by Draw05/Shutterstock

> Can we reduce phosphorus (P) rates and loss to the environment by banding? The thinking goes that any system that places P fertilizer below the surface without significantly increasing soil erosion will reduce P losses to the environment. Can application rates be reduced? The short answer is “it depends.” Decades of related research have conflicting conclusions. It’s of particular interest due to fertilizer prices and because agriculture is in the hot seat to cut P and nitrogen (N) losses to water bodies. Efficiencies from banding phosphorus (P) do exist in corn at very low soil-test P levels, where cool or wet conditions limit root growth and nutrient uptake, and in soils that make applied P less available.

Can we reduce phosphorus (P) rates and loss to the environment by banding? The thinking goes that any system that places P fertilizer below the surface without significantly increasing soil erosion will reduce P losses to the environment. Can application rates be reduced? The short answer is “it depends.” Decades of related research have conflicting conclusions. It’s of particular interest due to fertilizer prices and because agriculture is in the hot seat to cut P and nitrogen (N) losses to water bodies.

“If cutting P losses was easy, we’d already be doing it,” says Fred Below, University of Illinois corn physiologist.

The thinking goes that any system that places P fertilizer below the surface without significantly increasing soil erosion will reduce P losses to the environment. Banding P close to roots and close in time to crops’ metabolic need reduces mineral tie-up.

“Placing P in the subsurface at a 2-inch depth as opposed to surface broadcast will help P mitigate losses to the environment,” says University of Illinois soil science assistant professor Andrew Margenot. “The reduction amount is really tough to estimate because the relative improvement depends on so many variables.” He studies these P loss factors, including stream-bank loss, legacy P loss, and others that make the P loss conundrum so complex. He’s also part of a broad effort to quantify how much P loss comes from various ag sectors.

Antonio Mallarino, Iowa State University nutrient management specialist, suggests caution when speaking about the advantages of subsurface P application on P loss because six years of an Iowa study supports few strong conclusions (see Figure **1**).

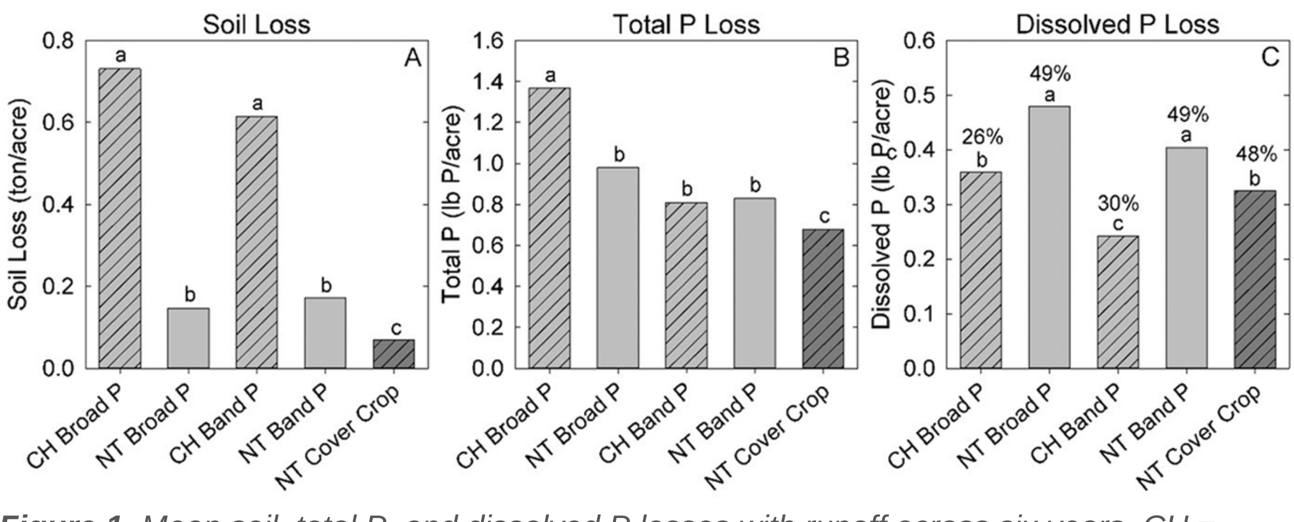


Figure 1, *Mean soil, total P, and dissolved P losses with runoff across six years. CH = tillage, NT = no-till. Numbers on top of the dissolved P bars indicate percent dissolved P of* *the total P loss. Source: **https://bit.ly/3Jm7HKN**.*

Despite theoretical efficiency gains from banding, land grant university research has not identified efficiencies to banding over broadcast or other application methods. Lower applied P rates, whether banded or broadcast, generally compromise yields.

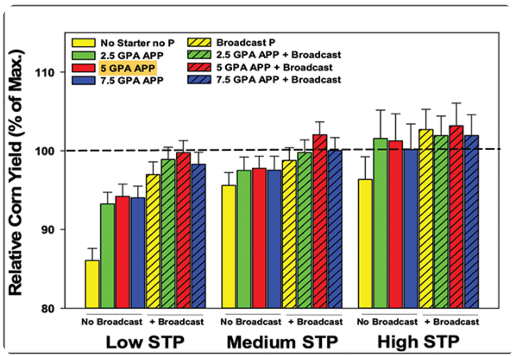
“Increased efficiency from banding is often associated with low-P-testing soils or calcareous soils with higher calcium carbonate content,” says Jeff Vetsch, University of Minnesota soil scientist and researcher at the Southern Research and Outreach Center. He researched the issue 20 years ago and again these past two years (Vetsch & Randall, **2002** and unpublished). “Most Midwest states do *not* recommend a P rate reduction when banding,” he says.

“Whether the P rate can be reduced by banding depends on crops and soil properties,” says Iowa’s Mallarino. “Banding P may be more efficient than broadcast in soils that ‘fix’ applied P in less available forms or when the soil surface is dry but there is moisture below. These soils may transform a portion of applied P into forms of low plant availability (often referred to as P fixation).”

Mallarino says he cannot recommend banding P in Iowa, based on yield data from his research, other than a small amount of starter P in a few specific conditions (Mallarino, **2013**). Forty years of Iowa research showed that banding or deep-banding P did not affect corn and soybean yields compared with broadcast fertilization for corn and soybean managed with tillage, no-till, strip-till, or ridge-till (Bordoli & Mallarino, **1998**; Borges & Mallarino, **2000, 2001**, **2003**). Many more additional trials with planter-banded P showed similar results (Mallarino, **2019**). Application rates in most of his trials ranged from 28 to 112 lb/ac P_2O_5.

By contrast, Minnesota recommends a 50% P rate reduction in corn when banding over broadcast rates. “Previous research found this to only be effective when soil-test P levels were low (6–10 ppm Bray or 4–7 Olsen) and very low (0–5 ppm Bray or 0–3 ppm Olsen),” Minnesota’s Vetsch says. “No P fertilizer rate reduction is given for soybean in Minnesota.”

South Dakota provides these provisos in its P-banding recommendations (**https://bit.ly/37eRDwO**): “Banding P and K near the seed as a starter frequently results in more efficient use of these fertilizers. Therefore, when starter P and K are used, rates can sometimes be reduced by one-third or more and still reach maximum yield. However, when rates are reduced, application may be below maintenance levels, resulting in a soil-test level decline with time, especially with P.”



This University of Minnesota study (***https://bit.ly/3K8gTn5****) compared corn yields at various rates of starter P as 10–34–0 (unhatched bars) to starter + broadcast P (hatched bars). “There was a corn yield response to P applied in the starter band, but at low soil-test P levels, broadcast P was needed to maximize yield,” says Jeff Vetsch, University of Minnesota soil scientist, who conducted the study* *with Daniel Kaiser, nutrient management specialist. At low and medium soil-test levels, broadcasting P (cross-hatched bars) was as important as the starter band (plain bars), but the two combined yielded better. At high soil-test P, starter alone increased yields, and anything after that did not matter compared with just the low starter (green unhatched bar). This study is unique in that the starter rate did not affect yields, Vetsch says. This multi-year study was conducted on glacial till soils in south-central and west-central Minnesota with pH ranging from calcareous to acid or moderately acid or neutral in the same field. This is a common scenario in southern Minnesota and parts of central Iowa.*

What Research Tells Us

Starter fertilizers containing P have been found to enhance early corn growth and yield, especially on poorly drained soils of the northern Corn Belt (Randall & Hoeft, **1988**; Vetsch & Randall, **2002**). The largest yield responses to starter P are often found with low soil-test P (Bermudez & Mallarino, **2004**) and on P-fixing soils.

Phosphorus Fixation and Highly Calcareous Soils

Phosphorus fixation sometimes is associated with highly calcareous soils with pH values above 7.4. A significant proportion of soils in the Dakotas and Minnesota have very high calcium carbonate content. Soils with high pH due to high calcium carbonate levels are common in mountain and western states, the Dakotas, and Minnesota. Strong P fixation may also occur in soils derived from volcanic ash or basalt, no matter the pH (mountain states, California, Oregon, and Washington) and also in extremely acidic soils with exchangeable aluminum (mainly in some soils derived from forests in the extreme northern U.S. and some areas in the southern and southeastern states).

"Fixation and soil pH can be tricky," Mallarino cautions. "Soil pH alone is not a good criterion for P fixation. Some U.S. soils have very high pH due to high exchangeable sodium or sodium salts, not due to calcium carbonate and *don't* fix P. … In Iowa, we have some soils with pH up to 8.2 or 8.3, but the calcium carbonate concentration is not as high as in other states, which explains why Iowa doesn't have significant 'P fixation.'"

Banding and Low-P-Testing Soils

"Banding's benefits should be most evident in low-P-testing soils," says Dan Kaiser, University of Minnesota Extension nutrient management specialist, who is collaborating with Vetsch on related research. "There's a tendency for low-testing soils to tie up P, but P efficiency gains are most evident in lower-testing soils."

No Yield Advantage (or Penalty) in Corn Found

Minnesota's Vetsch and Kaiser are conducting research to validate P fertilizer rate reductions when deep-banding compared with broadcasting on medium- and fine-textured soils in Waseca and Rochester. After two years, there's been no yield advantage or penalty in corn to deep-banding P fertilizer compared with broadcasting across a wide range of soil-test P levels and fertilizer rates.

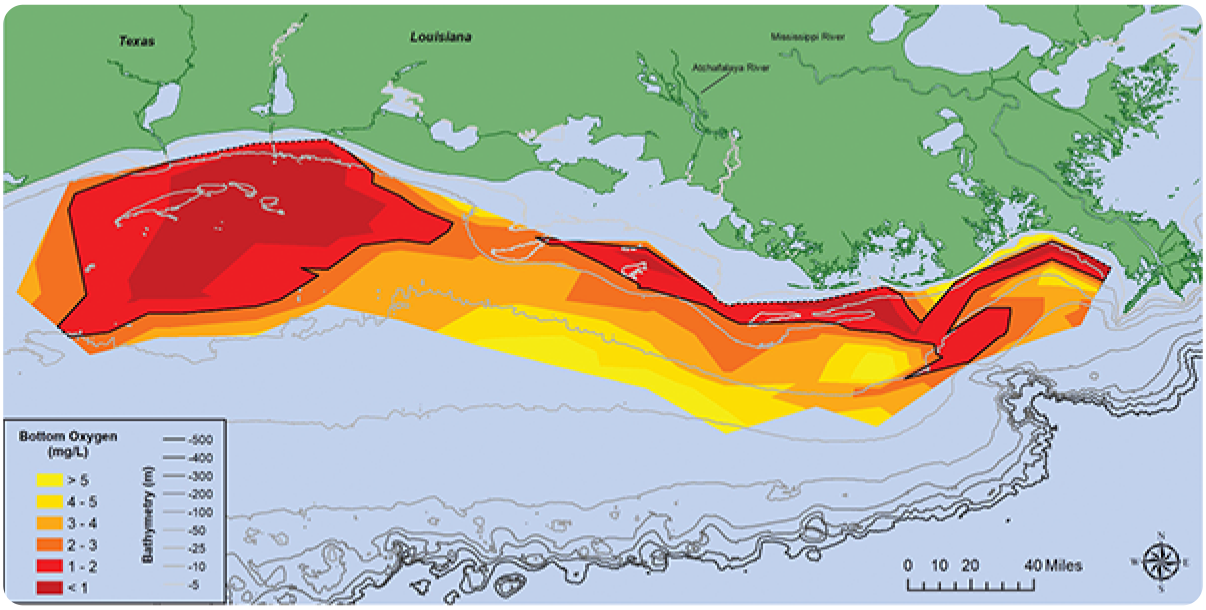
Fabian Fernández, University of Minnesota associate professor of soil, water, and climate, also recently studied P banding in depth. His recent central Illinois study also found no agronomic efficiencies to deep-banding P (Yuan et al., 2020). His eight-year research used three farmers' fields with six replications of each tillage × fertilizer rate × fertilizer placement treatment. The study was on flat, non-tiled silty clay-loam soil and silt loams using rainfall simulation to also study runoff. Both deep-banding and broadcast P applications produced virtually the same corn and soybean yields in strip-till.

“The P placement only impacts the crops if the soil is completely depleted of these nutrients or where fixation makes it unavailable,” Fernández says. In those cases, he says banding the fertilizer can improve P availability. “But those were not the conditions in this study, so the placement had no agronomic impact.”

The study found that deep placement reduced dissolved reactive phosphorus (DRP) loads by 69–72% over broadcast P applications. And DRP and total P concentrations remained low when P was deep-placed, regardless of P rate. When it comes to water quality, DRP losses from agricultural fields are the villains (see sidebar).

Fernández’ research team also found no difference in root growth resulting from broadcast or banding. “Most P uptake occurs in the top 2 to 4 inches, a good 2 inches away from the banding,” Fernández explains.

This supports his earlier research and that of Iowa’s Mallarino. Forty years of Iowa research showed that banding P with the planter or deep-banding did not affect corn and soybean yields compared with broadcast fertilization with tillage, no-till, strip-till, or ridge-till (Bordoli & Mallarino, **1998**; Borges & Mallarino, **2000, 2001**, **2003**), and additional trials with planter-banded P showed similar results (Mallarino, **2019**).



The size of New Jersey, the Gulf of Mexico "dead zone" has grown by thousands of square miles over five years. Illustration courtesy of NOAA.

Older research by Randall and Hoeft (1988) found that "Surface strip and deep subsurface bands (6-8 inches) outperformed broadcast applications when soil-test levels are low or reduced tillage is used." If the subsurface dries up, and you have P in a subsurface band, you will have a more difficult time getting water there to make P accessible to the crop than you would in the soil surface, the study found.

"At low soil-test levels, corn yields from [2 by 2 inch] band placement are seldom surpassed by other placement methods," wrote Randall and Hoeft.

"[Phosphorus] makes its way to the root by diffusion, which is very small," Iowa's Mallarino says. "Generalizations about banding P loss from fields and yield impacts are very risky. Guidelines based on local research is fundamental to assure profitable P management while minimizing impacts on P loss from fields and water quality."

Why Potential Banding Efficiencies Matter

Nine states contribute more than 75% of the nitrogen (N) and phosphorus (P) in the Gulf of Mexico while comprising only 33% of the 31-state Mississippi River drainage area, according to a U.S. Geologic Survey report (*see***https://on.doi.gov/3NNmWQ1**). Phosphorus loss also comes from livestock manure and industrial sources, but this article focuses on P losses from Corn Belt cropping systems.

Excess P is a particular problem causing algae blooms in freshwater bodies like Lake Erie and Lake Winnipeg.

Agriculture contributes more than 49% of P delivered to the Gulf of Mexico and about 60%

of delivered nitrogen (N) via runoff, subsurface flow, and erosion, according to U.S. Geologic Survey (USGS) studies. The goal is to reduce cropland nutrient loads to the Gulf by 45%.

Farm runoff and tile N and P fertilizer loss are blamed for starving fish and algae of oxygen, creating a massive Gulf of Mexico "dead zone." Causes include farm nutrient and manure runoff, plus sewage treatment plants and other industrial sources. The latter point-source pollution is regulated by USEPA permits. For now, farmers' agronomic P reductions depend largely on voluntary efforts (see **https://bit.ly/3DClsnj**).

The size of New Jersey, the dead zone has grown by thousands of square miles over five years.

Corn Belt P loss to the environment continues to exceed federal Mississippi Basin/Gulf of Mexico Water Nutrient Task Force goals. Although excess P is contributed by many sources, this article focuses solely on crop farmers' P losses.

Illinois, for example, sends the most P to the Gulf and is the second largest N contributor, according to USGS modeling. By 2025, Illinois aims to reduce P exports by 25%, plus greater long-term reductions. Instead, its P loads increased by 35% above a 1980 to 1996 benchmark, averaged from 2015 to 2019. This is according to the latest biennial Illinois report on its reduction strategy (see **https://bit.ly/3DGev4z**).

The USEPA regulates point-source pollution like industrial and sewage plants. More than a third of major municipal wastewater facilities in Illinois have permits that limit P discharge with more to come.

Land grant university research and Extension staff are charged with advising farmers how to reduce non-point P and N losses. "They've found that Illinois' high P losses are not from farmers overapplying it," Margenot says. "There's a trend since 2000 toward a negative P balance in Illinois. Some counties are even 30 lb/acre negative. We have good data that says farmers aren't actually overapplying P. [Phosphorus] loss to the Gulf is a result P erosion from the past."

Illinois can't seem to catch a break. Agriculture is also blamed for algae blooms in Illinois surface waters: This year, more than a dozen of Illinois water bodies sampled had toxin levels above recreation standards.

Phosphorus is needed by crops, but applications exceeding crop requirements build up P in soils and increase the likelihood of sediment-bound and dissolved P losses from fields, mainly with surface runoff after rainfalls and snow melts, causing problems. The timing of a runoff event after P fertilizer application greatly affects P loss, according to Antonio Mallarino, Iowa State University nutrient management specialist.

"Extensive Iowa research has shown very large dissolved-P losses in runoff events within a week or 15 days of P applications in no-till" (Mallarino & Haq, **2015**). This is the reason that in Iowa, P application in the fall, when runoff is unlikely, often results in much less P loss than applications in the spring when large runoff events are very likely, but this may not happen in regions with higher fall runoff."

Little is known about rainfall timing on P losses after P fertilizer application.

References

Bermudez, M., & Mallarino, A.P. (2004). Yield and early growth responses to starter fertilizer in no-till corn assessed with precision agriculture technologies. *Agronomy Journal*, **94**, 1024–1033. **https://doi.org/10.2134/agronj2002.1024**

Bordoli, J.M., and Mallarino, A.P. (1998). Deep and shallow banding of phosphorus and potassium as alternatives to broadcast fertilization for no-till corn. *Agronomy Journal*, **90**, 27–33. **https://doi.org/10.2134/agronj1998.00021962009000010006x**

Borges, R., & Mallarino, A.P. (2000). Grain yield, early growth, and nutrient uptake of no-till soybean as affected by the phosphorus and potassium placement. *Agronomy Journal*, **92**, 380–388. **https://doi.org/10.2134/agronj2000.922380x**

Borges, R., & Mallarino, A.P. (2001). Deep banding phosphorus and potassium fertilizers for corn produced under ridge tillage. *Soil Science Society of America Journal*, **65**, 376–384. **https://doi.org/10.2136/sssaj2001.652376x**

Borges, R., and Mallarino, A.P. (2003). Broadcast and deep-band placement of phosphorus and potassium for soybean managed with ridge tillage. *Soil Science Society of America Journal*, **67**, 1920–1927. **https://doi.org/10.2136/sssaj2003.1920**

Mallarino, A.P. (2013). Optimizing yield while minimizing phosphorus water quality impacts: Some do's and don'ts. In *2013 Integrated Crop Management Conference Proceedings* (pp. 165–173). Iowa State University. **https://bit.ly/3OOQw4W**

Mallarino, A.P. (2019). Phosphorus and potassium fertilizer placement options when crop prices are low. In *2019 Integrated Crop Management Conference Proceedings* (pp. 123–130). Iowa State University. **https://bit.ly/3uUi96V**

Mallarino, A.P., & Haq, M.U. (2015). Phosphorus loss with runoff after applying fertilizer or manure as affected by the timing of rainfall. In *45th North-Central Extension-Industry Soil Fertility Conference Proceedings* (pp. 94–99). International Plant Nutrition Institute. **https://bit.ly/3rOfNST**

Randall, G.W., & Hoeft, R.G. (1988). Placement methods for improved efficiency of p and k fertilizers: a review. *Journal of Production Agriculture*, **1**, 70–79. **https://doi.org/10.2134/jpa1988.0070**

Vetsch, J.A., & Randall, G.W. (2002). Corn production as affected by tillage system and starter fertilizer. *Agronomy Journal*, **94**, 532–540.

Yuan, M., Fernández, F.G., Pittelkow, C.M., Greer, K.D., & Schaefer, D. (2020). Soil and crop response to phosphorus and potassium management under conservation tillage. *Agronomy Journal*, **112**, 2302–2316. https://doi.org/10.1002/agj2.20114

More nutrient management

Back to issue

Back to home
