Science Societies

Soil health and 4R: What practices are working?

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December 29, 2020

Manure injection. Photo by Edwin Remsberg.

Soil health and 4R nutrient stewardship practices work together on farms to reduce nutrient losses. Farmers who work with the Soil Health Partnership (SHP) are adopting both at the same time. In the summer of 2020, SHP asked farmers about nutrient management practices on their SHP research fields between 2014 and 2019. This article focuses on the farmer-reported nutrient management practices from that survey in years where corn was grown on the SHP research field from 105 farms that reported nutrient management practices in at least one corn year.

Soil health and 4R practices work together to help farmers meet social, environmental, and economic goals. Soil health is the continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals, and humans (USDA-NRCS). 4R nutrient stewardship emphasizes applying the right source of nutrient, at the right rate, the right time, and in the right place. Supplying the soil and plant ecosystem with nutrients following a 4R framework is a key part of managing to advance soil health. In a 2018 survey of farmers about 4R nutrient stewardship, farmers identified soil health improvements as a driver for practice change with 67% indicating that getting 4R nutrient management right would improve soil health and crop performance (Moody, **2018**), demonstrating the strong link between soil health and 4R nutrient management by farms.

The Soil Health Partnership (SHP) partners with more than 200 farmers in 16 states across the United States. Each farmer works with an SHP field manager to design and implement an on-farm trial of a soil health practice or management system, including no-tillage or reduced tillage, cover crops, or advanced nutrient management, and SHP collects data on agronomic and economic outcomes to explore the economic and environmental benefits and risks of soil health practices.

While these practices all have impacts on 4R nutrient management on a farm, a few can be a challenge to nutrient application timing and placement and often will result in the farm needing to make adjustments to the source of fertilizer or the rate of application. For example, if during a transition to no-till, a farmer adjusts from incorporated to broadcast fertilizer application, it will have an impact on the 4Rs of phosphorus management in corn crops. Research has consistently demonstrated that placing phosphorus fertilizer to increase soil contact, as a liquid fertilizer or below the soil surface, decreases the loss of soluble phosphorus fractions (Qian & Harmel, **2015**; Williams et al., **2018**; King et al., **2018**). Other 4R practices like split nitrogen applications or the use of nitrification or urease inhibitors with nitrogen applications that can reduce nitrous oxide and nitrate losses are in harmony with many soil health practices (Eagle et al., **2017**; Omonode et al., 2017). Having a balance between soil health and 4R practices will be a key part of improving social, economic, and environmental outcomes for farmers.

Understanding which practices are working in the field for farmers can help inform research needs for economic and environmental outcomes and where to focus outreach dollars. As part of its collection of management data on research fields, SHP asked farmers in the summer of 2020 about nutrient management practices on their SHP research fields between 2014 and 2019. This included questions about fertilizer source, rate, timing, and placement. Farmers were asked about the total nitrogen, phosphorus, and potassium they applied; what percent of nitrogen was applied in the fall, in the spring before and at planting, and during the growing season; the primary method of fertilizer application; and whether any type of inhibitor was used along with fertilizer application (including nitrification or urease inhibitors). Data were also collected on whether manure was applied, including rate and source. For the purposes of this article, we focus on farmer-reported nutrient management practices in years where corn was grown on the SHP research field from 105 farms that reported nutrient management practices in at least one corn year.

Timing of Nitrogen Application

A field of corn stubble after manure injection. Photo by Edwin Remsberg.

Timing of nitrogen application can impact corn yield and nitrogen losses. For example, splitting nitrogen applications so that one occurs as a sidedress application during the growing season can reduce nitrous oxide emissions by 30 to 39% (Eagle et al., 2017). Nitrate losses from corn fields are largely influenced by rainfall and other weather conditions. Field-plot research in Iowa between 2015 and 2019 indicated there were limited differences in nitrate losses among the treatments of fall nitrogen applied as anhydrous ammonia with an inhibitor, spring anhydrous ammonia with no inhibitor, or split-applied nitrogen as a starter and a sidedress application because of the impact of water flow on the losses (Waring et al., 2020). Understanding the field conditions and weather has the largest impact on nitrogen uptake and losses (Eagle et al., 2017).

Seventy-one percent of field-years did not have fall nitrogen applied within the nutrient management practices data set of 214 field-years for corn across 105 SHP farmers. Of the 61 field-years where fall nitrogen was applied, only 31% had 100% of the nitrogen for the corn crop applied in the fall. Sixty percent of all of the field-years reported that at least some of the nitrogen applied for the corn crop was applied in season. Split nitrogen application is a common practice on these farms. For field-years with in-season applications, on average, 55% of the nitrogen applied for the corn crop was split from other applications to be applied in season. The percentage of the total nitrogen applied in season fell into three common ranges by the farms responding to the survey: 20%, 50 to 60%, or all nitrogen applied in season.

Use of Nitrification and Urease Inhibitors

The use of nitrification and urease inhibitors on both urea ammonium nitrate (UAN) and anhydrous ammonia applications has shown to decrease both nitrous oxide and nitrate losses. Research indicates nitrous oxide emissions can be reduced by 19 to 48% in corn production systems with the use of a urease inhibitor (Omonode et al., 2017).

Photo by Yolanda Oberhofer.

Between 2013 and 2019, 35.6% of the field-years used an inhibitor product with a fertilizer application in corn production years. In 2019, 34% of the fields where corn was planted used some type of inhibitor product with nitrogen applications in corn. This percentage of use can be better understood by linking more of the nitrogen management practices together because the choice to use an inhibitor product is related to the weather, soil, and crop conditions as well as timing of application. While there are economic and environmental benefits to their use, they are not effective in all settings at reducing nitrogen losses.

Methods of Fertilizer Application in Corn Years

Surface application of phosphorus that is not incorporated increases the risk for phosphorus loss from a field. Research has shown that injecting phosphorus fertilizer decreased dissolved reactive phosphorus loss by 66%, and incorporation of phosphorus fertilizer through tillage reduced loss by 75% when both were compared with surface application in a rainfall simulation study (Williams et al., 2018). It can be a challenge for farmers to balance soil health practices like no-till with the potential environmental benefits of decreased phosphorus losses to surface waters. For example, farmers may make the shift to no-till to decrease input costs, but they may need to make changes to how they apply and incorporate nutrients to maximize benefits.

Sixty-six percent of the fertilizer was applied using a method that places the fertilizer below the soil surface with banding, broadcast application followed by incorporation, or injection (Table 1). More information is needed to determine the types of fertilizer applied with these methods to understand the risk of the potential for loss. Of the individual practices reported, the most common method of applying fertilizer is broadcasting without incorporation—34% of farmers reported this as the primary method of application (Table 1).

Table 1. Primary method of fertilizer application on Soil Health Partnership farms in corn years.

Method of application	No. of farms reporting	Percent of farms reporting
	%	
Banded	37	26
Broadcast incorporated	17	12

Method of application	No. of farms reporting %	Percent of farms reporting
Broadcast not incorporated	48	34
Injected	39	28
Total reporting application method	141	

Expanding Adoption of 4R and Soil Health Practices

Understanding farmer management goals and how they measure progress toward these goals is critical to understanding the current landscape of practice adoption and how to provide farmers with the technical assistance and resources they need to support their adoption journey. An understanding of how farmers define "healthy soil," the value soil health brings to their operation, and how this drives management decisions is critical. Two soil health indicators that are relevant to farmers are soil organic matter and the role of soil health in water management; a recent study conducted in Texas with adopters and non-adopters of practices found that both groups valued these indicators and felt they contributed to economic and environmental benefits on the farm (Bagnall et al., 2020). However, studies of practice adopters and non-adopters have also found that the risks and costs of learning how to implement practices, such as cover crops, can deter farmers from trying a practice and sticking with it (Bagnall et al., 2020; Arbuckle & Roesch-McNally, 2015). These results indicate that combining the results of surveys, field research, economic analysis, and social interactions will be critical to continue as farmers work to make practice changes.

Conclusions

Soil health and 4R nutrient stewardship practices work together on farms to reduce nutrient losses, and farmers that work with the SHP are adopting both at the same time. However, as policies and programs push to increase practice adoption for environmental benefits (e.g., decreased nutrient losses) and as opportunities grow for farmers to participate in carbon markets, it is critical to continue to research the social, economic, and environmental impacts and interactions, including the synergies and tradeoffs of nutrient management practices in the context of a soil health management system.

nutrient stewardship

This article is part of a series from The Fertilizer Institute highlighting some of the latest 4R research.

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