

Improving farm nutrient management by optimizing organic matter inputs and root health

Principal Investigator:

Walter Goldstein

Michael Fields Agricultural Institute
East Troy, Wisconsin

Co-investigator:

Cynthia Cambardella

USDA National Soil Tilth Laboratory
Ames, Iowa

Farmer Cooperators

Practical Farmers of Iowa

Budget:

\$37,255 for year one

\$39,532 for year two

\$40,000 for year two

Abstract: Farmer cooperators conducted strip trials to help investigators create a nutrient and organic matter budgeting system that offered whole farm management guidelines to tighten nitrogen budgets for corn. Corn root health also was analyzed. An organic matter and nutrient budgeter was developed to help farmers to evaluate and plan more sustainable systems for their farms. The system was tested with farmers on individual fields and for whole farms. Strip plot trials were carried out to validate the budgeter's predictions. Root health was evaluated because it was believed to be associated with N uptake. The results of this research suggest that the health of corn roots is improved in management systems that use perennial forages and animal manures. Greater health is linked with less N uptake per bushel of corn produced. These systems are also predicted to have the greatest impact in building or maintaining soil organic matter. Conventional corn and soybean systems are associated with more disease, root growth, more N uptake/bushel of corn produced, and lower soil organic matter levels. Strip trials with and without fertilizer and manure revealed that corn was capable of extracting large quantities of N from soil organic matter without any fertilization. It appeared to be able to do this irrespective of total soil N content or quantities of biologically active soil organic matter. Root health and corn biology appeared to be a key factor relating to the success of organic farming or the problems associated with conventional farming. Clarifying linkages between corn root growth and N and C decomposition from soil organic matter would improve our ability to assess the impacts of corn cropping on long-term soil dynamics and would improve the budgeter.

Background

The importance of organic nutrient matter management for farming is highlighted by the fact that organic matter provides most of the nitrogen (N) that is utilized by corn, even when mineral N fertilizers are applied. Farmers who use sustainable farming practices and reduce and/or eliminate the use of mineral fertilizers must enhance the management of their soil organic matter if they are to be successful. This may include additional knowledge about how crop rotation and manure management strategies affect the pool of soil organic matter and available N.

The Organic Matter Budgeter Model was developed to help farmers identify how farm field balances of Active Organic Matter (AOM), Total Phosphorus (TP), and Total Potassium (TP) are affected by cropping history and by future plans for crop rotations, mineral fertilizers, and soil amendments. The budgeter calculates balances for individual fields as well as for the farm as a whole.

In the first two years of work on the budgeter in Iowa, the goal was to develop and perfect the budgeting and monitoring system, while learning more about how managing nutrients, organic matter, and root health might help tighten N budgets for corn without sacrificing yields. Investigators used strip trial experiments and constructed field-based budgets to validate the nutrient and organic matter budgeting model. Corn root health was studied in these trials because it was assumed that it might affect the efficiency by which corn could extract N from soil organic sources.

The work done with funding from the Leopold Center was part of more comprehensive set of trials that included farms in Illinois and Wisconsin as well as Iowa. Additional funding for the project came from the National Fish and Wildlife Foundation, the Audubon Society, W.K. Kellogg Foundation, the Illinois State Department of Agriculture, two U.S. Department of Agriculture programs (from SARE and EQUIP), and the Cavaliere Foundation.

Approach and methods

Methods of assessing root health were developed based on long-term studies (Wisconsin Integrated Cropping Systems Trials) and surveys of root health done in 2000 on 17 farms in Wisconsin and Illinois. Trials in 2001 and 2002 involved 12 Iowa farms (funded by the Leopold Center), 14 farms in Wisconsin, and five farms in Illinois. In 2001 and 2002, about half the farms surveyed were conventional and half organic, with and without livestock.

The field protocol was primarily replicated strip plots on one or two fields per farm, with and without manure and with or without mineral NPK (nitrogen, N; phosphorus, P; and potassium, K) fertilizer. The number of replications varied from one to three per treatment depending on the farm, site, and year. Budgets were prepared for 15 different two-year crop sequences, and 30 combinations of fertilizers and rotations.

Besides projecting how the different farming systems would affect the long-term buildup or decline of soil organic matter, the investigators devised nitrogen budgets for corn based on field data. These budgets helped provide estimates of how much nitrogen was mineralized

(released) from organic sources in the soil when the corn was grown. Root production and disease also were measured when the corn flowered and these results were related to nitrogen uptake and corn yield under different farming systems.

In the third year the budgeting system was extended to produce an overview of how management practices affected the balance of organic matter and nutrients on a whole-farm basis. The whole farm planning tool was tested by participating farmers (included ten Iowans) in order to see if it worked in practice and generated useful information. Field surveys completed by the farmers included historical field information on crop rotation, fertilizer and amendment applications, and results of soil nutrient testing. In addition, field slope, bulk density, and percent organic matter were estimated if actual values were not available. Budgets were calculated to show gains and losses of active organic matter, phosphorus and potassium on individual fields and on the whole farm.

Results and discussion

Budgeting results with individual fields in the different farm systems in the first two years suggested that conventional grain cropping systems often were depleting their soil organic matter resources. However, soils that employed rotations with grain crops and a high percentage of perennial forages were estimated to be accumulating organic matter.

The budgeter results were found to be useful for predicting excess nitrate in the soil profile in the fall over a wide range of farming systems. However, the budgeter routinely underestimated the quantity of nitrogen that was extracted from soil organic matter sources in the soil where cereals were grown and no fertilizer was applied. It used a fixed rate of decomposition (mineralization) to account for how much nitrogen will be released to corn from soil organic matter under different crops. In reality, corn seemed to take what it needed. It is not clear what mechanism is used by corn to extract N from soil organic sources, but this element is worthy of further study.

Wisconsin trials with various fertilizers suggested that fertilizers had greater effects on N uptake and grain yields on those sites where the unfertilized controls produced relatively low yields. On average, corn plants took up less nitrogen from fertilizers and more nitrogen from native soil organic matter sources than was originally expected. There was a wide variation in mineralization of manure-nitrogen from farm to farm.

Three years of field trials indicated that corn grown under conventional systems had almost twice as high disease scores (26 percent) relative to corn grown in organic systems (15 percent). The highest disease incidence was found where corn followed corn (30 percent) and the lowest presence of disease was present where corn followed organic soybeans. The most efficient systems for transforming soil organic nitrogen into grain were found where corn followed after alfalfa, alfalfa plus grass, or after soybeans in an organic rotation that included perennial forages and routine applications of animal manure.

Results from the whole-farm nutrient and organic matter budgets suggested that moderate decreases in P and K were occurring on most of the farms. Almost every farm had management units with contrasting losses or gains in these nutrients, which implies that even

within individual farms there were wide differences in losses. Gains and losses of soil organic matter were generally proportional to the original organic matter content of the soil. It was more difficult to maintain soil organic matter where native levels were higher than where native levels were low.

Conclusions

Some results of this study challenge both common thinking and the budgeter's initial assumptions of how soil fertility and management work. Despite evidence that mineral and organic fertilizers can cause large increases under some conditions, these results suggest that on average, the vast majority of N taken up by corn probably comes from soil organic matter even where fertilizers are applied. Corn seemed capable of obtaining most of the N it needs from soils over a wide range of organic matter-nitrogen contents, seemingly irrespective of the content of biologically active soil organic matter.

(PI: What practices provided the healthiest roots?)

Results also implied that corn grown under conventional farming systems and in organic small grains/clover systems squandered the organic nitrogen resources of the soil, as they were both inefficient at turning soil organic nitrogen into grain yields. It appeared to take a lot more N to grow a bushel of conventional corn in a corn-corn or corn-soybean system (1.8 lbs N/bushel) than it took to grow corn in an organic system after soybeans or forages (1.4 lbs N/bushel). This inefficiency may be due to biological factors associated with rotations and soil quality, such as root disease. In any event, the most efficient systems for nitrogen and corn production appeared to involve alfalfa-grass mixtures and ruminant manure application. These forage and livestock-based systems also had the greatest potential for carbon retention in the soil within soil organic matter.

A significant question arising from this research relates to the mechanism by which corn can extract so much N from soil organic matter and how this may or may not be coupled with the decomposition of carbon from soil organic matter. More information on this mechanism is needed to adjust the budgeter to better estimate N release and carbon decomposition from organic matter. Furthermore, it would be valuable to clarify whether the reasons for the efficiency of certain systems are truly due to differences in root health.

Areas for fruitful future research also might include assessing whole farm nutrient and organic matter budgeting, developing methods for better assessing organic matter retention on farms, and further testing of corn production, nitrogen and organic matter dynamics in conventional systems and in farming systems that involve alfalfa-grass mixtures and manure applications.

Impact of results

The organic matter and nutrient budgeter that was developed for the project was used by 60 farmers to better utilize their organic matter resources. The budgeter helps to make plans and calculate organic matter and nutrient losses and gains due to different practices.

Budgeting results suggested that integrated crop/livestock systems were the most sustainable with respect to maintaining or enhancing soil organic matter levels.

Results from on-farm trials indicated that corn was capable of extracting large quantities of N from soil organic matter sources. These results could help scientists and farmers begin to change the way they think about soil fertilization; they can shift from being fertilizer-based to being root-driven when working with corn.

Limitations to efficiency in converting N to grain appeared to be associated with corn grown in conventional grain cropping systems and grain/green manure systems. Corn raised in conventional systems also had greater root growth and nearly double the amount of root disease compared to systems that included perennial forages and a history of manure application.

More root growth for conventional systems was associated with greater N uptake from soil organic matter, leading to inefficient N use. Perennial forages and organic manures was associated with greater disease suppression and greater N efficiency. The linkage between root disease, root growth, and N uptake is very possibly the cause for a need for a soil building conversion plan that involves organic manures when farmers choose to reduce the use of chemicals. Root disease may have caused the 'cold turkey' phenomenon (nutrient deficient plants, poor competitiveness with weeds) associated with the green manure systems in the trials.

Education and outreach

Outreach activities for the project included:

- Visits, discussions, and farm reports for individual fields and for whole farms provided to participating farmers in all three states;
- Reports on overall results presented at the Practical Farmers of Iowa annual conferences and research planning meetings in 2002, 2003, and 2004;
- Reports and budgeting workshops held with individual farmers at the Upper Midwest Organic Farming conference in LaCrosse, Wisconsin;
- A report on the results shared at the annual researcher/farmer meeting of the Wisconsin Integrated Cropping Systems Trials in 2002;
- Results displayed during courses on organic soil management at the Organic University in LaCrosse, Wisconsin in February 2004 and 2005; and
- An invited presentation given at the American Society of Agronomy Organic Symposium in fall 2003.

For more information contact Walter Goldstein, Michael Fields Agricultural Institute, P.O. Box 990, East Troy, WI ; (262) 642-3303, wgoldstein@michaelfieldsagainst.org