Optimizing nitrogen cycling through soil management to nurture beneficial fungi

Patrick Ewing
Ph.D. Student
Advisor: Nick Jordan

Nitrogen (N) management is a major challenge to Upper Midwest corn production. Not only is N a major cost to growers, but late-season fertility needs are difficult to predict (Sawyer et al. 2006). This uncertainty historically comes from two areas. First, a temporal disconnect between pre-planting fertilizer application and peak crop N demand means mineral N has much opportunity to leave an agricultural system through leaching or denitrification and causes environmental damages (Mengel, 1995). Additionally, corn acquires the majority of its N from mineralized soil organic N rather than fertilizer, an inconsistent pathway that can fail to meet demand and suppress yields (Sawyer et al., 2006). Since both mineralization rates and nutrient loss pathways are microbially mediated, they vary widely depending on rainfall, soil water status, and soil temperature (Chapin et al., 2012).

Climate change will further destabilize N management. Over the next fifty years, the Upper Midwest will face more extreme weather - more droughts, more heavy rains, and more variation in spring planting environments (Mark Seeley, 2012, personal communication). These extremes pull the same soil environment levers that alter N retention and N availability, and thus exacerbate the instability of N management, yields, environmental costs, and grower risk.

As the key mediators of N transformations, soil microbial communities are central to coping with this management challenge. Early season N stabilization through microbial assimilation and immobilization can minimize losses. As these microbes grow, they form organic N residues including a potentially mineralizable N (PMN) pool that is readily converted back to mineral N that plants can access (Franzluebbers et al., 1994).

While all microbes are important, fungi are in a unique position to drive tighter N cycling and ease N management. Arbuscular mycorrhizal fungi (AMF), plant mutualists that are dependent on their host for carbon (C), are important C sources that both alter soil biology and stimulate decomposition (Jansa et al., 2013). Meanwhile, saprophytic fungi that form hyphae bridge the gap between alternate resource pools of crop residue and mineral N (Six et al., 2006). Emerging evidence suggests that AMF and saprophytic fungi play complimentary, keystone roles in N cycling: AMF as a fresh C source to stimulate microbial activity, and saprophytes as a ‘highway’ transporting N and C among existing soil pools.

My goal is to explore ways to manage this fungal activity such that it tightens N cycling in agroecosystems. Manipulating the soil environment using precision zonal management (PZM), which is an umbrella term for a group of tillage methods, holds promise for accomplishing this goal. PZM, including ridge till and strip till, is unique from more commonly practiced, uniform management systems like chisel plowing or no till in that it creates distinct soil environments between the row and furrow. These environments vary in terms of disturbance, water availability, temperature, and residue location - the same factors that shape fungal communities and N cycling.
Our results suggest that PZM also creates unique bacterial and fungal communities between the row and furrow, while uniformly managed chisel plow fields do not show such strong differentiation. I hypothesize that these different communities are especially robust and effective at forming a PMN pool in the ridge till furrow due to the creation of an ideal soil environment.

To test this hypothesis, I am first identifying general patterns of C input from corn roots and AMF hyphae that stimulate decomposition between PZM and non-zonal management systems. In general, I expect zonal fields to show a more horizontally distributed rooting pattern and greater colonization than chisel plow fields, suggesting that they also direct more C to surface soils. I also am identifying soil environmental characteristics that nurture especially diverse fungal communities at on-farm and long-term research sites. I am characterizing the fungal communities in response to row and furrow environments in PZM and non-zonal systems using next-generation sequencing; collaborators are measuring a suite of other environmental and biophysical variables that define these environments. I expect that, in general, communities in wet environments with residue concentrated at the surface will be both more diverse and enriched for hyphal-forming saprophytic fungi rather than yeast-type saprophytes, independently of the disturbance regime.

Finally, to link communities from different soil environments to an ability to stimulate PMN formation, I will measure nutrient cycling in zonal and non-zonal systems after altering C sources by excluding AMF or removing crop residue. I expect that, in the first month of the growing season when crop demand is low, PZM fields will show the most PMN formation. High PMN formation will correlate with high mineralization after a midseason disturbance. Non-zonal and C removal treatments will show lower PMN formation and higher early season mineralization - not a good outcome for reducing early season nutrient losses.

The implication of these expected results is that the furrow environment that PZM creates will nurture a robust and active community of nutrient-cycling fungi. These communities will be able to more effectively utilize all available C sources to stabilize mineral N into organic N as PMN. With the midseason disturbance of re-riding in ridge till systems, this PMN may then mineralize and become plant available at peak demand. Both stabilization and mineralization will contribute to more stable and efficient nutrient management, reducing grower risk and environmental damage.