RESTORING SOIL QUALITY AND PRODUCTIVITY

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Agricultural producers face considerable economic challenges as they prepare for the future. In an effort to remain profitable many cash grain farmers have changed their cropping systems to include more frequent planting of high-value but nutrient demanding and pest-vulnerable crops (e.g., potato, sugar beet, tomato and snap bean). Many potato growers have shortened rotations (over 80% of potato producers in central MI now use 2- or 3-year rather than 4-year rotations), and 3-year sugar beet rotations are common. Frequent production of vegetables, potatoes and sugar beets has led to yield declines, compacted and poor quality soil, and increased pest problems.

The development of cropping systems that reduce tillage intensity, increase the use of cover crops and make efficient use of manure in the crop rotation can protect the environment and improve soil quality in many ways. Low-disturbance tillage and soil conservation practices that stabilize soil will keep soil nutrients in place and protect water quality. Cover crops prevent erosion and filter contaminants in runoff. They have also been shown to improve water-stable aggregation of soil and increase water infiltration compared to soil without cover crops (McVay et al., 1989). As soil aggregation improves, soil structure and tilth also improve (Allison, 1968).

What is soil quality?

Soil quality brings together those physical, chemical and biological characteristics that enhance its ability to efficiently produce quality crops, protect the environment, and provide ecosystem services to the farm and the local landscape (Harwood, 2004). Some of the *physical characteristics* of soil quality are:

- Optimal structure for stand establishment and crop/root growth.
- Minimize wind or water erosion.
- Provide for water infiltration, drainage and aeration.
- Retain crop-available moisture.
- Maintain aggregate structure.

Some of the *biological factors* are:

- Maintain balance of pests and pathogens.
- Mobilize nutrients when needed for crop growth, but minimize leaching loss.

And, some of the *chemical factors* are:

- Supply crop nutrients as needed for crop growth.
- Retain nutrients and crop residues within the field and in the upper soil layer.

The soil environment and soil ecology is defined by a complex and interrelated web of physical, chemical and biological factors. If you create conditions that maintain soil quality you will reap the benefits that quality soil offers. If you overwhelm the soil environment with excessive tillage, traffic or erosion from wind and water; mine nutrients and organic carbon; or use crop rotations that upset the biological balance of pests, pathogens and microbes…efficient and profitable crop production will not be easy.

Managing the farming system for soil quality

Tillage operations are important in most farming systems. Tillage is used to prepare a seedbed; control weeds, insects and disease; manage soil compaction and crop residue; and incorporate soil amendments. So it is difficult to reduce tillage operations on many farms. But tillage generally degrades soil quality by breaking down aggregate structure. Stable aggregates are created slowly by natural processes, but they break down quickly under the action of tillage tools. Look for opportunities to combine field operations and reduce tillage intensity when managing for soil quality.

Soil compaction is the loss of pore space in the soil. Pore space is needed for drainage and oxygen exchange, root growth and efficient nutrient use. Tillage and traffic are the primary cause of most soil compaction. Soil symptoms of compaction are crusting; a cloddy seedbed; standing water; and an absence of plant roots in the soil. Common plant symptoms are variable emergence; variable size; wilting; and yield decline.

Soil compaction can be shallow--in the normal tillage zone; deep--below the normal tillage zone; it occurs in all soils--including mucks and sandy soils; and is most likely in poorly drained, fine-textured soils. Machinery can damage soil from compression, shear and vibration. Generally, 70% to 90% of tire sinkage and bulk density change occurs on the first pass, and repetitive traffic drives compaction deeper.

Excessive tillage contributes to soil compaction, but judicious tillage is a fast and effective way to reduce compaction. Tillage can increase pore space in the root zone and improve infiltration and drainage, but tillage induced pores are not structurally stable and do not effectively resist traffic induced soil compaction. After years of reduced tillage, soil is more resistant to traffic.

Natural processes alleviate compaction and improve soil quality

In the long-term, soil compaction can be reduced by natural processes that cause the soil to shrink and swell such as wetting and drying, freezing and thawing. Root growth helps fracture compacted soil. Plant roots and soil microbes produce exudates that form natural glue in forming stable soil aggregates. Earthworm activity inverts soil and creates channels for water infiltration and root growth.

Reduce tillage intensity; add organic inputs--manure and cover crops

Reducing tillage intensity is important, but you can't simply no-till your way out of a soil quality problem on the weathered, low organic matter, shallow top-soil, soil series characteristic of the upper Midwest, Northeast and Atlantic states. To make an impact in a reasonable period of time you also need additional organic inputs--manure and cover crops. Cover crops protect the surface from wind and water erosion, recycle plant nutrients, improve water infiltration and add organic carbon to the soil. Manure provides many of the same benefits. Both manure and cover crops increase organic matter and water holding capacity; improve aggregate stability and water infiltration; and decrease evaporation and soil bulk density.

Create a comfortable seed environment

A goal in profitable and efficient crop production is to create an optimal seed environment. An optimal environment provides the right soil temperature and allows seed-to-soil contact for rapid germination and emergence, maintains good soil tilth for root growth and drainage, and conserves moisture for plant use.

Managing the farming system for soil quality is a real challenge, yet many Michigan producers are changing their farming systems with soil quality in mind. In the quest for soil quality it is important to understand that there is no single tillage tool, crop or management practice that will solve a soil quality problem. Building soil quality means managing the entire farming system--tillage and planting practices, cropping systems and rotations, harvest and traffic patterns. Look for opportunities to reduce tillage frequency and intensity, and use cover crops and manure to protect the environment, recycle nutrients and build stable soil aggregates.

Putting it all together--slurry-enriched seeding of biosuppressive covers

Cover crops in the *Brassica* (mustard) family may offer benefits in some rotations beyond soil conservation. Forage radish crops have been used to alleviate compaction in coastal plain soils in Maryland (Williams and Weil, 2004). Oilseed radish has been shown to suppress sugarbeet cyst nematode (Hafez, 2005). In Michigan, sugarbeet yields increased about two ton/ac following an oilseed radish cover crop (Poindexter, personal communication; 2004). The incorporation of oriental mustard (*Brassica juncea* L., variety Pacific Gold) in the spring before planting potatoes suppressed *Rhizoctonia solani* by 73%, and the cover was highly suppressive of fungal activity by *Pythium ultimum*, and *Fusarium solani* (Snapp, S.S. and K.U.Date, 2004).

Manure that is high in nitrogen and soluble (available) carbon has been shown to suppress soil borne pathogens (Conn and Lazarovits, 1999; Tenuta, 1999). These studies reported that poultry and swine manure were the most consistently beneficial manure sources for reducing *Verticillium dahliae* and common scab in potato. Recent findings from long-term research trials have shown a consistent and significantly greater yield response of potatoes, vegetables and field crops to manure applied with a winter cover crop than manure to bare soil alone (Sanchez et al., 2004; Snapp et al., 2004). There are two important processes by which organic inputs enhance biosuppression and improve soil and root health: 1) biochemical compounds and 2) available C and N that supports soil organisms, enhances competition and suppresses pathogen rebound (Gamliel et al., 2000). *Brassica spp*. and sorghum-sudangrass residues contain high levels of glucosinolates. During tissue decomposition, toxic compounds are produced that have antifungal, nematicidal and bactericidal properties (Lewis and Papavizas, 1974; Morra and Kirkegaard, 2002; Stapleton and Duncan, 1998).

Recent work at Michigan State University has compared stand establishment and biomass yield of oil seed radish (varieties Common and Colonel) and oriental mustard (Pacific Gold) established as a summer seeding in wheat stubble with conventional no-till drilling, and a new process--*manure slurry-enriched micro-site seeding-- whereby aeration tillage, manure application and seeding are done in a single, efficient operation*.

Each crop was sown with a no-till drill and with a new manure slurry-enriched seeding process where a slurry tanker (3,000 gal) was equipped with a rear-mounted rolling-tine aerator (12 ft; Aer-Way)[1] and SSD (sub-surface deposition) slurry distribution system. Seed was placed in the spreader tank where bypass flow provided tank agitation and seed mixing. The slurry (both dairy and swine slurry have been used successfully) passed through a hydraulically driven, rotating chopper/distributor (300 rpm) with radially configured outlets connected to drop tubes. The drop tubes delivered the seed-laden slurry to the fractured soil behind each set of rolling tines.

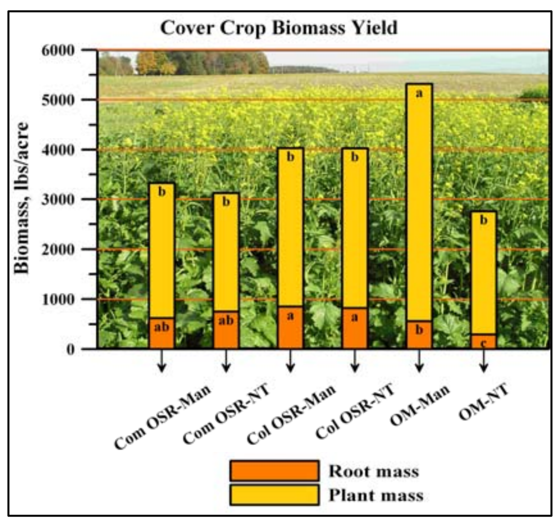

Figure 1 Oil seed radish biomass production was similar with no-till and slurry-enriched seeding, but oriental mustard was greater with slurry seeding.

Results

The plant stand with the slurry seeding process was lower than no-till seeding, but the biomass yield was equal or better than conventional no-till seeding. Total biomass from the six treatments is shown in Table 1. There was little difference in above-ground plant and root mass between no-till and manure slurry enriched micro-site seeding with either variety of oilseed radish. However, the above-ground plant mass, root mass and total biomass of the oriental mustard was significantly greater with the slurry seeding process. Additional work is in progress.

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[1] Mention of trade names, proprietary products, or specific equipment is intended for reader information only and constitutes neither a guarantee nor warranty by Michigan State University, nor does it imply approval of the product named to the exclusion of the products.