Building Soil Health and Marketable Yield through Crop Rotation

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based on presentation and published papers from Dr. Robert Larkin, USDA-University of Maine
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Defining Soil Health

Soil Health can be defined as the continued capacity of soil to function as a vital living system to sustain biological productivity, maintain environmental quality, and promote plant, animal and human health.

Emphasis is placed on the importance of all the multiple functions of soil, including biomass production, nutrient cycling, filtering and buffering, water storage/availability, biological habitat, biodiversity. Building and maintaining soil health is essential to agricultural sustainability and ecosystem functions.

The Importance of Healthy Soil Communities

An essential component of soil health is fostering an active, diverse soil microbiological ecosystem. These soil microbes are necessary for decomposition of plant residues, nutrient cycling and availability, building soil structure, breakdown of toxins, and suppression of disease causing pathogens. Soil-borne diseases are usually most severe when soil condition are poor, such as inadequate drainage, low soil organic matter, poor soil fertility, high soil compaction, and low microbial diversity.

Key to maintaining a diverse microbial ecosystem is soil organic matter, as it is the primary food source for these microorganisms. Mainting sufficient soil organic matter levels as well as a diversity of plant species has been shown to promote microbial diversity, which in turn can help keep disease-causing pathogens (bacteria, fungi, nematodes, etc) in check.

Key Soil Health Management Strategies include:

- **Manage Soil Organic Matter**
- **Minimize Soil Disturbance (Tillage)**
- **Diversify Soil Microbial Communities**
- **Maintain Living Plants**
- **Maintain Soil Cover**

Improving Soil Health through Crop Rotation

Numerous studies across many potato-growing regions have highlighted the value of a number of plant species as "disease suppressive crops." These include *Brassica* species (mustards, canola, rapeseed, kale, radish, etc), sorghum sudangrass, pearl millet, buckwheat, and others. Some of these crops can act as "biofumigant" crops (ie. brown mustard), where incorporation of the crop releases volatile chemicals into the soil that can reduce the populations or activity of disease-causing microorganisms. Other crops can inhibit disease through other processes, like root exudates, but the maximum effect of disease suppression is usually seen when incorporating these crops into the soil during the growing season as a "green manure."

Soil-borne pathogens and pests that have been shown to be controlled in this way include black scurf (*Rhizoctonia*), common scab (*Streptomyces scabies*), powdery scab (*Spongospora*), early dying complex (*Verticillium* spp. and root lesion nematodes), and wireworm, among others.

While incorporation of organic amendments has long been associated with building soil organic matter, the choice of crop species, frequency and method of tillage, and use of cover crops can all have a significant impact on maintaining or building soil organic matter levels, and in turn, fostering beneficial soil microbial communities.

USDA - University of Maine Crop Rotation Study

Starting in 2004, Dr. Robert Larkin led a team at the US Department of Agriculture (USDA) and the University of Maine in Presque Isle to investigate the effect of different types of rotations on soil health characteristics, disease suppression, and marketable yields in potatoes. These rotations were followed until 2012.

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The rotations in the study consisted of:

Status Quo (SQ):	Potato - Barley underseeded to Red Clover
Soil Conserving (SC):	Potato - Barley underseeded to Timothy - Timothy. Featured limited tillage and straw mulched
Soil Improving (SI):	Potato - Barley underseed to Timothy - Timothy. With addition of compost
Disease Suppressive (DS):	Potato - Brown Mustard (green manure) with Rapeseed cover crop - Sudangrass (green manure) with Fall Rye cover crop
Continuous Potato (PP):	Potato every year

Some of the key finding from this study included:

- The Soil Improving (SI) rotation, featuring addition of compost, had significantly improved values for soil moisture, water stable aggregates, bulk density, total soil C, total soil N, active C, CEC, and microbial biomass. For most of these variables, the Soil Conserving (SC) rotation had the second best values.
- For non-irrigated production, the SI rotation also had the highest marketable yield. Under irrigated conditions, the Disease Suppressive (DS) rotation had the highest yield, followed by the SI rotation.
- The DS rotation significantly reduced levels of black scurf and common scab on tubers.
- Current research is focused on modifying these rotations to confer similar benefits but be more economically feasible.

Investigating Green Manure Crops

An additional study by Dr. Larkin's team investigated the effect of different rotation crops for their effect on disease suppression and marketable yield under different types of crop management.

The crops studied included brown mustard, sudangrass, rapeseed, soybean and barley. Each of these crops was then assessed when incorporated as a green manure, left as a cover crop (not incorporated), harvested with stubble incorporated, or harvested with no incorporation of residues.

Key observations from this study:

- Incorporating any crop as a green manure was associated with an increase in marketable yield more than any other type of management.
- Green manures had the strongest effect at lowering black scurf severity.
- Use of mustard (regardless of management) had the highest effect on tuber yield and black scurf reduction.
- Sudangrass and rapeseed also showed greater effect on yield and black scurf reduction than soybean or barley.
- Incorporation of mustard as a green manure was the best individual treatment, increasing tuber yield by 20-25% while decreasing black scurf by 51% over barley managed as a cover crop.
- Compared to harvested barley, green manuring mustard showed a $259/acre improvement in net income in a two year rotation with potatoes. Harvesting mustard was shown in economic analysis to potentially return even greater improvements in net income.

Key Recommendations for an Ideal Potato Rotation:

- Having a rotation of at least three years in length, using conservation/reduced tillage where possible.
- Use of a disease suppressive crop like mustard or sudangrass before the potato year. Ideally, this crop would be incorporated as a green manure and then followed with a cover crop (ie. fall rye).
- Another commercial crop (ie. barley, soybean, canola) can follow the potato crop in rotation.
- Addition of compost or other organic amendments, where available, to improve soil organic matter and yield potential is recommended.

Additional details on this research can be found at:

Larkin, R.P. and Halloran, J.M. *Management Effects of Disease-Suppresive Rotation Crops on Potato Yield and Soilborne Disease and Their Economic Implications in Potato Production.* American Journal of Potato Research (2014) 91: 429-439

Larkin, R.P., C.W. Honeycutt, T.S. Griffin, O.M. Olanya, Z. He, and J.M. Halloran. 2017. *Cumulative and residual effects of different potato cropping system management strategies on soilborne diseases and soil microbial communities over time.* Plant Pathology (online) DOI: 10.1111/ppa.12584