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Exploring the Relationship Between Soil Health and Food Nutritional Quality:

A Summary of Research Literature

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A Summary of Research Literature

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Executive Summary

Introduction and Approach
Many on-farm and environmental benefits associated with improving soil health are well established, but the relationship between soil health and human health through food nutritional quality remains largely unknown. To investigate this relationship, peer-reviewed literature was searched and analyzed with the objective of evaluating the potential link between soil health and food nutritional quality. Four criteria were used in selecting literature for evaluating soil health and food nutritive quality relationships. Namely, each study was evaluated for providing:

- comparisons of crop and soil properties under different land management practices or cropping systems;
- measurement of soil health related parameters under different management practices or systems;
- measurement of crop nutritive characteristics; and
- measurement of outcomes relevant to human health (or, at minimum, consideration of human health outcomes in interpreting the data).

Findings
Initial searches for literature produced as many as 1,000 results, but few papers contained enough relevant information for addressing the objective of this evaluation. Subsequent searches were then conducted using keywords for specific soil health management practices in combination with terms related to crop nutritive outcomes. This yielded more relevant papers, as did including specific crop terms. After an initial survey of a broad assortment of crops, the review was narrowed to examining published evidence connecting soil health and crop characteristics for tomato (*Lycopersicon esculentum* Mill.) and wheat (*Triticum aestivum* L.) due to their nutritional, economic, and agronomic importance in North American agriculture and similar agricultural systems.

Focusing initial searches with keywords relevant to soil health-promoting agronomic management practices and keywords specific for crop nutrition or nutritive value yielded 72 papers that offered enough information to be useful. Of these, 37 focused on row crops (e.g., corn, wheat, soybean) alone or in rotation with one other. The remainder were publications on tomato, rice, potato, butternut squash, bean, chickpea, broccoli, cassava, or berries. Publications demonstrating causal links between soil health and crop nutritive changes were rare, with most limited to documenting the effect of land management on crop quality and only hypothesizing that soil parameters influenced nutritive differences. Possible causal mechanisms linking soil health-promoting management practices and crop nutritive value included:

- changes in microbial diversity,
- changes in nutrient cycling,
- effects on arbuscular mycorrhizal fungi and other fungi that colonize crop plant roots and affect nutrient uptake,
- plant response to environmental stressors associated with land management practices,
- presence of perennial plants or a leguminous crop in annual cropping systems, and
- changes in soil physical and chemical properties affecting crop water and nutrient uptake.

Sixteen papers compared nutritional outcomes in organic and conventional production systems. Of these, only a few reported soil measurements. A paper describing a meta-analysis of 74 studies comparing organic and non-organic farming systems concluded that soils in organic farming systems had significantly higher levels of soil organic carbon (SOC), greater carbon stocks, and greater carbon sequestration rates than conventional systems. In general, principles relating SOC with mineral nutrient availability in soil support a mechanism linking SOC with crop nutritive value. However, differences in nutritional composition of organic crops could not be attributed to changes in soil health because most of these publications lacked key soil health and crop nutrient measurements.

WHEAT GRAIN PROTEIN CONCENTRATION WAS OFTEN INCREASED BY INCLUDING A LEGUME CROP IN ROTATION

Wheat

There is considerable interest in the effect of tillage intensity and crop rotation on grain quality and yield. The influence of tillage intensity on grain protein concentration or content (concentration x harvested mass) was inconsistent among rotations, among years within individual experiments, and among publications. In contrast, wheat grain protein concentration was often increased by including a legume crop in rotation, even though different experiments included different crop rotation combinations and durations. In many cases, rotation with a legume resulted in increased protein content and yield, likely related to N availability from legume crop residues. Increased soil organic matter and soil total N in some rotations may have promoted root growth, which in turn increased water and nutrient uptake. Diversifying continuous monocrop wheat systems or replacing fallow with another crop, commonly a legume, increased grain Zn concentration in multiple studies. A significant increase in grain Zn occurred in rotations with perennial crops, e.g., alfalfa-hay, possibly related to higher soil organic matter and an associated increase in cation exchange capacity, or presence and function of arbuscular mycorrhizal fungi. The effect of crop rotation on the concentrations of other macro- and micronutrients (K, Ca, S, Mg, P, Fe, Mn and Cu) was inconsistent across studies.

Tomato

Most of the 12 publications that compared effects of agronomic management systems on tomato nutrient composition focused on comparing outcomes of organic and conventional production practices. Most studies lacked key data for assessing relationships between production practices and crop nutritive value, e.g., data on mineral nutrient concentrations in both soil and fruit, or yield data for calculating crop nutrient content. In some papers, but not all, organic production systems resulted in significantly different concentrations of macro- and micronutrients in tomato fruit, compared to conventional systems. However, apparent treatment-related changes described in some studies (e.g., changes in mineral concentration in association with yield change) were not observed in others. Similarly, organic production practices led to increased concentrations of lycopene and β-carotene in fruits in some experiments, but not others.

A GENETIC COMPONENT TO TOMATO CROP RESPONSE TO MANAGEMENT ALSO APPEARED TO INFLUENCE RESULTS

In addition, a genetic component to tomato crop response to management also appeared to influence results. For example, one tomato cultivar exhibited a significantly higher ascorbic acid concentration under organic production than under conventional practices; however, the same observation was not made for a different tomato cultivar. Source of N in fertilizer (organic or synthetic) had no effect on concentrations of phenolic compounds that are important antioxidants, nor in chemical activities of soluble antioxidants. It seems plausible that when management practices on tomato nutritive quality were observed, they could be linked to different levels of nutrient availability and cation exchange capacity in soils managed organically compared to conventionally. However, the many different management practices applied and their highly diverse and individual impacts on soil physical, chemical, and biological characteristics, render data from organic vs. conventional systems highly confounded. Thus, comparisons and conclusions about the effects of organic vs. conventional management systems were difficult to discern.

Conclusions and Recommendations

Although both wheat and tomato are widely produced and consumed crops, only a small number of publications included data appropriate for evaluating soil health with crop nutritive quality. This finding reflects the lack of attention that has been given to investigating the relationships between soil health and food nutritional quality.

Determining causal mechanisms among soil health management systems, soil health outcomes, crop nutrition, crop nutritive value, and human health requires research that must include specific, carefully selected, and highly controlled or characterized aspects of soil, crop, and human nutrition-relevant variables. To address these issues, we recommend future research studies be conducted that include:

- well defined, consistently applied soil health-promoting management practices,
- relevant and methodologically consistent soil health measurements,
- methodologically consistent measurements of general soil conditions (physical conditions, mineral nutrient concentrations, etc.),
- methodologically consistent crop nutrient measurements (concentrations of mineral nutrients, plant secondary compounds, proteins, and others in consumed plant tissues relevant to human health),
- crop yield measurements,
- methodologically consistent indicators or measurements of human health attributable to nutrition, and
- a diversity of crops that reflects the human diet globally.

Experiments, measurements, and methods should be selected specifically to enable translation of results into meaningful implications for human health. This must be achieved by interdisciplinary research teams, including human nutrition experts, to interpret connections between agronomic data and dietary impact. Understanding the connections among soil health, crop nutrient concentrations/content, and human health is essential to guide future land management policies and practices, as well as to address consumer demand. Such additional research is justified to meet global sustainability, nutritional, and food-security goals.

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