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Soil Health: Its Role in Today's Orchard Systems. Introduction and Synopsis.

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Worldwide, more attention is being paid to soil health as people recognize its critical role in sustaining much of our agricultural food system. The USDA Natural Resources Conservation Service (NRCS) has launched a new soil health initiative to focus more attention on the soil resource (USDA-NRCS, 2013). And more and more growers are asking what they can do and are implementing specific practices that benefit soil health.

A common definition for soil health (or soil quality, used synonymously) is the "capacity of a soil to function … to sustain biological productivity, maintain environmental quality, and promote plant and animal health" (Doran and Parkin, 1994). While measurements such as pH or soil texture represent soil properties which are generally fairly stable, soil health is more an evaluation of a particular soil based on human needs. With soil pH, there is no inherent good or bad level – it depends on what we want to grow. A soil pH of 4.7 might be ideal for blueberries but not for peas. So measurements of soil health, which are still rudimentary and challenging, always come back to the purpose for which humans want the soil to perform.

One difficulty in understanding soil health is that of finding an appropriate reference point. For wheat grown in Kansas, the native prairie is the obvious reference point. The closer soil health can be to the prairie, the better wheat should grow. But for orchards in central Washington, grown under irrigation, what is the proper reference point? Should we measure the soil in native apple forests in Kazakhstan and compare those to our orchard soils? Or do we need to create our own reference point here based on testing different management and observing the response of the tree, fruit, economics, and environment? A quantitative approach like this was undertaken in the Yakima Valley with a long-term study of soil health under three different management systems: conventional, integrated, and organic (Glover et al., 2000). The site had not previously been in orchard, and thus replant disease was not a factor. Indicators of soil health were typically improved with the organic and integrated systems where various organic amendments were added. But once tillage for weed control in the organic system started, soil health declined.

The soil is a complex system consisting of physical, chemical, and biological properties that all interact with one another. For example, soil compaction (physical) can change soil aeration and affect the oxidation-reduction potential (chemical) as well as soil organisms (biological). Right in the center of all this is soil organic matter, probably the most widely measured or regarded element of soil health. Organic matter also affects physical, chemical, and biological properties, and improving it has long been seen as key to soil health. But in an ecosystem such as central Washington where native soil organic matter levels are low, and it is difficult to raise them, how essential is this to improving soil health? Can we grow an equally good orchard and fruit crop through careful irrigation and nutrient management versus raising soil organic matter? How critical is the soil biology (dependent on the organic matter) to a high performing orchard? Soil biology has long been the least studied aspect of soil, and much remains to be learned (Moore-Kucera et al., 2008).

Soil health can change, for better or worse. Mulching the tree row (Table 1) has led to measurable improvements in tree growth, fruit yield, and soil biological function (Forge et al. 2003). Growing apples on a soil with no previous history of apples generally leads to a change in the microbial community that we call "replant disease", an undesirable outcome. Long-term fertilization of the tree row in central Washington orchards with acid-forming fertilizers changed the pH from 6.7 in the drive alley to 4.2 in the tree row. Other management practices that affect soil health include incorporating soil amendments, weed control, fumigation, recycling of prunings, choice of fertilizer, irrigation system, and use of different cover crops both in the drive alley and the tree row. The different management zones (alley and tree row) in an orchard system add complexity to the evaluation of soil quality, since a site is no longer uniform.

During the Soil Health session, speakers presented their data and experience on three specific questions. The first question was "Does organic matter matter?" In our low organic matter soils, research results have not shown a consistent correlation between soil organic matter level and orchard performance. In the longest running orchard floor management trial in the U.S., Ian Merwin saw a dramatic increase in soil organic matter with periodic mulching, and that treatment led to the greatest tree growth, but not a greater fruit yield. The carbon from organic matter, particularly the more 'labile' or available forms, is a key food source to support the soil food web which provides many functions. George Bird saw a large increase in soil biology in the surface "duff", much like the litter layer in a forest. The nematode community was most favorable with mulches, and there were almost no root lesion nematodes with alfalfa mulch. It took seven years for the orchard soils to come to a new "dynamic equilibrium" with the different management treatments. One question that was raised was about proper sampling. How should we be sampling soils for organic matter and soil biology, especially if there is a "duff" or mulch layer? Gerry Neilsen remarked that practices to raise organic matter may show little benefit if there is not an important soil limitation, such as water holding capacity, which they overcome.

The second question addressed during the session was "How do we measure soil health?" Currently the most common measures used in orchards are chemical tests of soil, leaf, and fruit samples. Gary Johnson explained that many of the soil test extractant methods currently used were developed for Midwestern and Eastern U.S. soils that are more highly weathered and often more acidic than our young soils in the Columbia Basin. He agreed with others that there has been relatively poor correlation between soil test results from these methods and positive responses in our orchards. He has explored other approaches to soil testing and analysis, including the cation balancing approach (designed to maximize forage quality for cattle in Missouri), saturated paste extraction, and use of the farm irrigation water as the extractant. Even sample preparation can affect the outcome – grinding versus not grinding a soil sample led to a 27% difference in the results. He said that both ratios of nutrients and their absolute abundance are necessary to consider in terms of providing sufficient tree nutrition and maximizing fruit quality. Gary is currently exploring water extractable carbon and the Solvita test as alternatives to total carbon for an indicator of soil biological potential. Tom Forge described a number of measures of soil biology, many of which are research oriented and not suitable or available for routine grower or consultant use. Microbial status can change rapidly over time and has high inherent variability. There are also tremendous differences between measurements taken in the rhizosphere (the soil right around the root surface) and the bulk soil, raising another question about the best way to sample. He has found free living nematodes to be a good indicator of the soil food web. At this point, he recommends total carbon, active carbon, microbial biomass, and nitrogen mineralization as a group of tests to evaluate the soil biology. But more work needs to be done to relate these to specific outcomes for orchard performance.

The third question addressed was "How does management influence soil health and tree performance?" Ian Merwin described his long-term orchard floor trial in New York. Early on, the grass sod (in the tree row) treatment looked worse in terms of tree performance, but showed some positive effects on soil health. Over time, the apple trees appeared to compensate and the differences became minor. However, the negative economic consequences of the grass treatment would argue against this approach. All his systems showed a positive balance for nitrogen, and there were some treatment effects on leaching losses in certain years, a soil health consideration. The Cornell Soil Health Index was calculated for the different treatments, and a higher rating correlated with tree growth but not fruit yield or quality. Mike Omeg described his efforts for improving orchard performance with modest investments in the soil, a part of the system that has lagged in terms of management attention. He is interested in boosting the role that the soil biology plays in cycling nutrients in his orchards. Use of straw mulch led to a large positive response in his trees. He has tested various soil stimulants and has measured increases in fruit size in weak cherry blocks. He uses an Aerway tool to help combat compaction in the drive alley to allow for better entry of air and water. Cover crops other than grass are being tested in the drive alley, including tillage radish. A large study on compost use showed that compost can improve tree performance on weak blocks, but had little effect on healthy blocks. It led to an increase in fruit size with a ¼" or ½" application on the tree row, and the type of compost made a difference. With the better quality compost at ½" application, he more than covered the cost to buy and spread the compost, and the two composts differed by $800 per acre in gross revenue while costing the same. Gerry Neilsen remarked that in his various trials, mulching the tree row led to a significant improvement in orchard performance 66% of the time, and an incorporated amendment improved things 30% of the time.

Overall, several take-home messages emerged. Our understanding of organic matter and soil tests as they relate to soil health come primarily from Midwestern prairie soils and annual crops. They do not necessarily fit our young, low organic matter, irrigated soils and perennial orchard systems. Poor soils do respond to soil amendments and surface mulching in particular. On a good site, with proper irrigation and sufficient nutrient, these practices often show no benefit. There is no current agreement on proper soil testing methods that correlate well with orchard performance. When sampling for organic matter or soil biology, standard procedures need to be developed since there are large differences among the bulk soil, the rhizosphere, and the surface "duff". More tests are commercially available to help evaluate soil health, but they need to be better correlated with tree response. Much remains to be learned about how to predictably manage the soil biology for outcomes such as nutrient cycling and disease or nematode suppression. And finding proper reference points for orchard soil health indicators remains elusive.

Invited speakers for the session were Dr. Gerry Neilsen, Agriculture and Agrifood Canada, Summerland, BC, Canada; Dr. George Bird, Dept. of Entomology, Michigan State Univ., E. Lansing, MI; Gary Johnson, Wilbur-Ellis Inc., Wenatchee, WA; Dr. Tom Forge, Agriculture and Agrifood Canada, Summerland, BC, Canada; Dr. Ian Merwin (retired), Dept. of Horticulture, Cornell Univ., Ithaca, NY; and Mike Omeg, Omeg Orchards, The Dalles, OR.

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Table 1. Effects of several mulches on soil health indicators in apple – Summerland, BC.

	Trunk size (cm^2)	Fruit yield (kg/tree)	Infiltration (L/hr)
Check (no mulch)	11.5 b	14.7 b	5.5 b
Vancouver mulch	11.6 b	14.7 b	14.6 ab
Paper mulch	17.4 a	20.4 a	10.0b
Weed fabric	12.4 b	16.0 b	3.4 c
Trial planted in 1994, 'Spartan'/M.9. Measurements taken in 2001. (Neilsen et al., 2003)			