Soil Health for Tree Fruit: An International Perspective

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Contrasting Soil-Tree-Climate Associations

**Annapolis Valley, NS Lat. 45° N**

Maritime Climate
- short, cool growing season
- non-irrigated orchards
- long, cold winters
- precipitation: 1150 mm

**Western Cape, SA Lat. 33° S**

Mediterranean Climate
- long, hot, dry growing season
- permanent irrigation systems
- short cool winters: insufficient chilling
- precipitation: 750 mm pa mostly winter
Soil Health:

“the capacity of soil to function as a vital living system, within ecosystem and land use boundaries, to sustain plant and animal production, maintain or enhance water and air quality, and promote plant and animal health.

Healthy soils are the ones which sustain biological productivity, store and cycle water and nutrients, decompose organic matter, inactivate toxic compounds, suppress pathogens, protect water quality and enhance catchment’s health.”

Three Soil Health Topics

1. SA and NS Approach to Drainage of Orchard Soils
What is an optimally drained soil?

- has the capacity to drain gravity before oxygen and root health
- for soils prone to water that is achieved after
What are the spin-offs of improving soil drainage?

- investment in soil health
  - > exchange of $O_2$ and $CO_2$ exchange
  - < production of anoxic gases: CO, NO
  - reduces risk of root diseases
  - soils less susceptible to compaction
  - improved nutrient uptake
  - < frost heaving (NS)

- improves trafficability

- greater tree uniformity

- earlier, higher production of quality fruit
Internal and External Drainage

Internal drainage: refers to the net permeability of all soil layers in a profile.

External drainage: refers to the position of the soil in the landscape.
Soil variability
Considerations for Artificial, Sub-surface Drainage Systems:

- soil investigation
- properties of the subsoil
- LT rainfall distribution patterns
- wettest year in 10
- classic “herring bone” design or selected drainage of wet areas?
- design: depth and spacing
Healthy roots: cool soil temperatures; soil OM; sufficient moisture
Performance of Subsurface Drainage Systems for Orchards

Most critical period: Post bloom
Weather: wettest year in 10
Rooting Zone: 60 cm
Saturated root zone: 150 mm water
Soil temp: 12 °C

DR of 2.5 mm hr⁻¹: 60 hours
DR of 25 mm hr⁻¹: 6 hours

Red Delicious / M793
Fairfield Farm
Warm Bokkeveld, Ceres, SA
Digging for facts is better than jumping to conclusions.
Surface modification for removal of excess water?

Syn: berms, ridges, landscaping

- shallow, wet soils with some slope to work with
- investment in topsoil
- improves soil depth = “soil health”
- enhances orchard uniformity
- often in conjunction with upslope cut-off drainage
Surface Modification for Removal of Surface Water

Model: Informal Landscape
Non irrigated orchards

Model: Formal Landscape
Non irrigated or drip irrigation

Model: Formal Table Top
Permanent micro-irrigation
Incorrect height to width ratio

Problems with:
- increases soil temp, ET
- difficult to irrigate
- impractical for equipment
Soil variability
Reshaped surface to improve drainage
Planting row
Don’t try to solve the problem after planting!
Western Cape – SA

Soils 30,000 + yrs old

> challenges with subsoil permeability

> emphasis on surface removal of water

Subsurface drainage; only selected situations

Annapolis Valley, Nova Scotia, CA

Soils < 10,000 yrs old: since last ice age

> fewer challenges with subsoil permeability

> emphasis on tile drainage (30 + % of all soils)

Surface modification in selected situations
Soil Health

2. Replant Disease: a big challenge
Greenhouse for running replant bioassays
Non-fumigated check
Effect of soil pH on the reaction to fumigation with MB
P deficiency
Untreated replant soil

Sterilized replant soil

Untreated potting mix
Response of ‘Honeycrisp’ Apple Trees to Combinations of Pre-plant Fumigation, Deep Ripping, and Hog Manure Compost Incorporation in a Soil with Replant Disease

P. Gordon Braun, Keith D. Fuller, Kenneth McRae, and Sherry A.E. Fillmore

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Replant Soil: Orthic Humo-Ferric Podzol
Birchleigh Farm, Nova Scotia

Bioassay for Replant Disease:
- apple seedlings grown in greenhouse
- significant response to pasteurization of soil
- ARD root pathogens *Pythium* and *Cylindrocarpon* sp. isolated
Compost used
Deep ripping
Replant Treatments:

1. Control
2. Fumigation: Telone C17 @ 280 L per ha
3. Deep ripping
4. Deep ripping + fumigation
5. Deep ripping + compost incorporation

Replant Site:

1. Apple production since 1942
2. Old trees removed summer 2001
3. Land plowed down: fall 2001
4. Treatments established: fall 2002
5. Honeycrisp® / M4 planted spring 2003
Growth Response of Honeycrisp / M4 to Replant Treatments

Reference:
Yield of Honeycrisp® / M4 in Response to Replant Treatments with compost

metric tons ha\(^{-1}\)

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<tr>
<th>Year</th>
<th>Treatment</th>
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<tr>
<td>2005 4th leaf*</td>
<td>Control, Telone, D Rip, DR C, DR C F</td>
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<tr>
<td>2006 5th leaf</td>
<td>Control, Telone, D Rip, DR C, DR F</td>
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<tr>
<td>2007 6th leaf</td>
<td>Control, Telone, D Rip, DR C, DR F</td>
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*Planting year
Honeycrisp® trees growing in composted treated ARD soil.

Honeycrisp® trees growing untreated ARD soil.
Effect of deep ripping, fumigation and compost on root numbers in the 80 cm of soil

Reference:
Compost suppression of soil borne diseases*

- production of antibiotics or fungitoxins by microbial populations in compost
- destruction or absorption of phytotoxins by compost or the organisms it supports
- improved plant nutrition and vigour
- induced systemic resistance by microbes in compost
- successful competition for nutrients by compost supported micro-organisms
- parasitism of pathogens by compost supported microbes
- beneficial changes to the physical characteristics of the soil
- beneficial changes to soil pH / salt concentration

Other observations

- Symptoms of “Honeycrisp® chlorosis” were more pronounced in control trees when compared with trees receiving compost.

- Trees in the control site were still visibly smaller after 6 years and had not filled allotted space.

- Severity of the disease at this site generally fits the prognosis that ARD is more pronounced on coarse textured mineral soils with average to low OM and the likelihood of moderate to severe levels of drought stress.
Biological remediation of Apple Replant Disease with composts and animal wastes
Summary of Research and Field Experiences with Replant Disease in SA and NS

- a major re-establishment issue in both industries ... apples and pears


- Greenhouse: best growth response in replant tests on soils with low pH – worth pursuing

- Field: many replant sites fumigated with an observational control – almost always a good response

- Field: observations generally showed more severe replant symptoms on coarse textured soils with average to low soil OM and moderate to severe drought stress

- Viable alternatives to broad spectrum fumigants: currently none
Soil Health

3. Nitrogen Utilization Efficiency: Soil Health Indicator
Studies in N use efficiency and water quality in Annapolis Valley orchards


- MacSpur / MM107 and MM111
- 400 trees per ha
- Orthic gray-brown-luvisol
- Tile drained orchard
- 3.4 % OM
- Grassed orchard floor, only broadleaf herbicides
- Std pruning / thinning practices
Methodology: Nitrogen Applications and Mulching for MacSpurr

1. Permanent under-canopy mulch
   - 2.4 x 2.4 m sq per tree
   - 5 kg per tree per pa (5 cm)

2. Nitrogen applications
   - hay mulch each spring
   - 5 kg hay per tree (1.2 % N)
   - equiv: 24 kg N ha⁻¹
   + 150 g AN / tree to mulched area
   - equiv. to 20 kg N ha⁻¹
   =
   Total: 44 kg N ha⁻¹ each spring

3. Grassed orchard floor

4. Broadleaf herbicides to eliminate N fixation.
Methodology: N leaching

- tile drainage system to collect leachate
- continuous monitoring of flow
- collection of composite water samples
- calculation of nitrate loading (kg N ha\(^{-1}\))

Methodology: N removal by crop

- harvesting of fruit (fresh + drops)
- calculation of yield
- use of industry norms for fruit N content
- calculation of N removal from system
Results: N removal by crop

- production: 40 metric tons ha\(^{-1}\)
- N removal: 16.8 kg N ha\(^{-1}\)
- vs applied: 44 kg N ha\(^{-1}\)
Results: tile NO3-N concentrations

- fall, winter and spring periods
- > 30 composite samples each drainage season
- 0.5 – 2.0 mg NO3-N L^{-1}
- << drinking water standard: 10 mg N L^{-1}
Results: nitrate loading

- < 2 kg N ha⁻¹ annually
- most during the dormant season
- approximately 5% of applied N
tile N03-N concentration

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<th>Apples</th>
<th>Forage</th>
<th>CSW</th>
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<td>1.0</td>
<td>5.0</td>
<td>9.0</td>
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Possible reasons for high N utilization

- berms: more topsoil under the canopy
- application of hay mulch: builds soil C, stores N, gradual release
- orchard is a no-till / extreme reduced till system
- optimal rooting environment under the much
  > branching of root system
  > higher than normal root density
  > higher % utilization of N, only 5% lost by leaching
    = approximately 5 % of applied N

= SOIL HEALTH
Comments on N utilization efficiency in orchards

South Africa vs Nova Scotia

**Soil OM content:**

1 - 3 % vs 2 – 4 %

**Leaching potential:**

750 + 500 mm vs 1150 mm

**Ave. Annual Temperature:**

15°C vs 8 °C
Thank You !