Audio Book Companion

For the Love of Soil

Strategies to Regenerate Our Food Production Systems

Nicole Masters
Introduction

Chapter 3  To Bring Vibrant Life To

Soil Health Principles

* Maintain soil groundcover and protection.
* Living roots for as long as possible.
* Incorporate livestock and/or their manures (where feasible).
* Diversity, diversity, diversity.
* Optimise plant photosynthesis.
* Reduce disturbance - minimise killing your underground livestock.
* Manage for what you want, not what you don't want.
* The actions which arise from these principles are influenced by your specific climate and circumstances.
Chapter 5 First there was light

To increase mycorrhizal colonisation and activity:

* Firstly; stop the actions which are killing them!
* Remove chemical ‘i-cides. Buffer herbicides with fulvic acid and avoid high soluble phosphate.
* Increase plant diversity.
* Inter-crop alley crops between cash crops. There are cover crop species which are rich sources of AMF spores; Flax, Sorghum, Millet, Sudan Grass, Sunflowers and Oats. Even trees, which may have ecto-mycorrhizae, have a stimulatory relationship with the AMF in grasses.
* Use carbon-based inputs and biostimulants to encourage underground diversity.
* The presence of plant growth promoting bacteria (PGP) partners such as yeasts, pseudomonas fluorescens and bacillus species work in partnership to increase the efficacy of MF.

If mycorrhizae are critically low:

Stimulate and feed MF with soluble humates, compost extracts or vermicast. If you are planning to apply herbicides or cultivate a field, then the addition of soluble humic or fulvic products is a must to support your beneficial MF populations. Mix fulvic with herbicides, or drip onto soil when cultivating. Do not miss an opportunity to feed your essential micro-herd!

* You can make a mycorrhizal inoculant – combine potting mixes with soil/leaf materials collected from local healthy ecosystems. Grow AMF spores in soil using C4 grasses, such as Sudan grass, Paspalum spp, Corn etc.
Image of photosynthetic process.
How can you tell if your soils are compacted? Digging a hole is a good start. Compacted soils often have plate-like structures, roots will be shallow, shear off or travel sideways. Other indicators include fine soil crumbs, surface crusting, thatch and high insect or disease pressures. These areas will have higher water stress, less plant growth and slower recovery. In compacted areas, water will pond or run off, plants such as moss or deep-rooted weeds will grow.

Want to get a clearer more accurate measure for compaction? A penetrometer is a tool you can purchase on-line and use to monitor current conditions and measure changes over time. It gives you a reading based on how many PSI it takes for a root to push through the soil. Take your penetrometer and push it into soil. Ideally, do this when your soil is at a Goldilocks moisture level, not too wet and not too dry (generally spring following rains or snow melt). Don’t push too fast, ideally one inch per second.

As resistance increases beyond 300PSI, root penetration drops. There may still be some roots that will get through that layer, but they’re generally sparse and in poor shape. Being able to open up soils and increase root penetrations like this, has huge broad-reaching positive implications well beyond the farm gate; improving water quality and reducing greenhouse gases.
Image: 3D X-ray computed tomography of the two soils. Soil at the top is from the IPM, on bottom is Nick Patterson’s. Image with Permission from Plant and Food Research New Zealand.
Graph showing changes in Spring soil sodium levels at Lindsay Farms. 2012 was the first-year irrigating with brine. Late 2015 biological products applied.

Legume Nitrogen Fixation

Dig a hole; do your legumes have copious amounts of nodules and are the nodules large? When you pinch or cut open a nodule, is it pink or blood red in colour?

If the nodules are white- then they have not been fixing N. Time to put on your detective hat...
- Do you have low functional molybdenum (Mo) or cobalt (Co)? Both trace elements are involved in essential enzymes to metabolise N.
- Is the soil already high in nitrogen? Have you been adding nitrogen or high rates of manures?
- Is the soil saline, alkaline or highly acidic?
- Did you inoculate your crop and is the inocula present in the soil? If nodules are green, the plant has been fixing and now the process has stopped. Ask why?
  - Have there been environmental stressors?? Cold soils will stop fixation in some species, as will drought and low sunlight.


Chapter 7 Drinking It In

**Infiltration rates** are measured in mm/minute. (25mm = 1 inch). It's simple to calculate. Just divide the depth of water, by the time it takes to soak in.

It is critical that water soaks in faster than 2 mm/minute or 120mm/hour; any slower and you’ll be losing water to run-off during storms; and under lighter rain, any water that falls, will just evaporate.

*Image: cordyceps mushroom growing out of native New Zealand caterpillars.*
**Soil carbon is a giant sponge**

An increase of 1% carbon can increase soil water holding capacities by the following amounts:

- Soils less than 10% clay – 20 to 30% increase
- Soils 10 to 15% clay – 10 to 25% increase
- Soils 15 to 20% clay – 10 to 18% increase
- Soils > 20% clay – about 10% increase or less.

The USDA determined the water holding capacities of organic matter (OM). Depending on soil type, a 1% increase in OM in a loam soil, increased water holding by 187,000 litres/Ha or 20,000 gallons an acre, (calculated as water holding capacity down to 30cm depth in a loam soil). Now this result is based on one moment in time; with drying and wetting cycles varying through the year, it may be 3 times this amount—nearly half a million litres/ha/year, or 43mm of additional stored water.
**Chapter 8 Break It Down**

Digging a hole reveals more obvious clues when digestion has stalled, like thatching, ‘bad’ smells, gray oxidised layers on the surface or sharp changes in colour between topsoil layers.

The OM test includes all living materials in soil, not just humus and carbon. This measure may also contain thatch, plant roots and dead organisms smaller than 2mm in size. If your soils contain high levels of undecomposed organic matter, it may give you a false high reading. Humus and glomalin tests give a better picture around microbial conversion of the raw organic materials into more stable humus forms. However, these tests are less common and more expensive.

You can also request a carbon to nitrogen (C: N) test to help identify if your carbon is functional. In healthy soils, with a good decomposition cycle, this test will read a C: N ratio between 10:1-12:1. If your ratio is lower than 10:1, you have an excess of nitrogen in the system burning your carbon up. A low C:N ratio can correspond to an excess of nitrogen in the system, rapid turnover of organic materials and burning up of carbon.

If the ratio is above 12:1, your soil decomposition cycle is stalling. This can lead to a build-up of thatch and a slower breakdown of manure and plant materials. As microbes work to breakdown C, they will rob N from the plants. High C: N ratios relate to the following combinations: mineral imbalances, low pH, low or imbalanced biological activities. These are the constipated soils.

This C: N test is a crude indicator that organic materials are converting to humus in the soil.
Earthworm benefits

- Improve water absorption and prevent erosion.
- Reduce slaking—increase the water stability of the soil, earthworm castings can take a direct hit by a raindrop and maintain their shape. This reduces erosion and runoff, hence helps the soil absorb water.
- Soil with earthworms dramatically increases infiltration and water holding capacities. A research study in Minnesota cornfields, demonstrated that earthworms increased water absorption 35 times greater than control fields without the earthworms. At 100 nightcrawlers per square meter, 50mm (2”) of water could be absorbed by the soil in 12 minutes, versus 12 hours without earthworms.
- If the top meter (3 feet) of soil contains over 25% macropores (earthworm burrows), that soil should be able to absorb at least 220mm (9”) of rainfall before running off or ponding.
- Studies involving the introduction of earthworms to pasture soils show an immediate increase in productivity, usually in order of 70%.

Natural anthelmintic plants

Plants with natural parasitic properties include forbs such as: Wormseed mustard (*Erysimum cheiranthoids*), Indian pinks (*Spigelia marilandica*), Common purslane (*Portulaca oleracea*), Chicory (*Cichorium intybus*) and Narrow leaf plantain (*Plantago lanceolata*); legumes such as Birdfoot trefoil (*Lotus corniculatus*), Sainfoin (*Onobrychus viciifolia*), Sulla (*Hedysarum coronarium*) and Lotus major (*Lotus pedunculatus*); as well as browse species, like Willow (*Salix spp*), Black walnut (*Juglans nigra*), Oak (*Quercus spp*) and Erect Canary Clover (*Dorycnium rectum*).

Support your above and below-ground livestock

To speed up success, stop killing your clean-up crew!

Cultivation, anthelmintics, carbamate insecticides and fungicides are all detrimental. Avoid using any long-residual chemicals.

If crop residues are slow to breakdown, apply a digestion spray.

Address the six major ingredients required for microbial digestion: air, water, sugar, Ca and a little N, P.

Optimise groundcover, introduce organic materials. Bio-stimulants such as vermiliquid, liquid seaweed/fish, will feed the bacteria and fungi that earthworms and insects love.

If you do use anthelmintics, create a refuge for dung beetles and other insects, by leaving at least 20% of your livestock untreated. Use sacrifice areas during chemical withholding periods.

Reduce animal stress during handling, drought, weaning, calving. Provide shelter. Practice good rotational grazing practices, avoiding overgrazing or set stocking.

Run a diversity of livestock.

Have a diversity of forage; many forbs and fodder shrubs have natural anthelmintics.

Support animals nutritionally, with free choice minerals and humate, supplements and probiotics.
Chapter 9 High Input Transitions

Graph: Canadian farm income, debt, imports and exports, 1970-2013. Source Statistics Canada.

Graph: United States retail store bread price and farm-gate wheat price, 1975-2016. Source Darrin Qualmin.
<table>
<thead>
<tr>
<th>Product</th>
<th>Application</th>
<th>Rate/ac</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMF Trichoderma P-solubilising bacteria</td>
<td>Seed treatment</td>
<td>300 mls</td>
<td>Applied per Tonne of seed</td>
</tr>
<tr>
<td>10 10 10 NPK Fulvic acid Boron (21%)</td>
<td>Foliar</td>
<td>14 litres</td>
<td>Total kg = 0.6 N, 4.7 P, 3.4 K</td>
</tr>
<tr>
<td></td>
<td>On peas only</td>
<td>300 mls 0.2 pound</td>
<td></td>
</tr>
<tr>
<td>Soluble humic</td>
<td>Furrow</td>
<td>1 litre</td>
<td>This is a commercially tailor-made product.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>In year 2 the gypsum was applied separately.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Recorded as actual amount of trace elements</td>
</tr>
<tr>
<td>Gypsum Humate Sea minerals Boron Zinc Copper</td>
<td>Furrow</td>
<td>35 pounds 25 pounds 4 pounds ½ pound ½ pound ½ pound</td>
<td></td>
</tr>
<tr>
<td>Urea</td>
<td>Between rows</td>
<td>25 pounds</td>
<td></td>
</tr>
</tbody>
</table>

Chart of Year one inputs at Twin Rivers. This is not a general prescription; this is a programme to address specific enabling factors on this farm.

Graph showing changes in OM from 2016 to 2019. Despite the poor growing seasons, over a 3-year period, most of the benchmarking sites showed significant lifts in organic matter. The only 2 sites with a decline in OM, were swath grazed as the snows melted, causing a significant amount of soil damage. Site 3 had large visible changes in soil structure, moving from compacted states to a light, fluffy and aerated soil.
Chapter 10 Measuring Success

<table>
<thead>
<tr>
<th>DM Basis</th>
<th>'Supreme'</th>
<th>Bio Alfalfa</th>
<th>Control Alfalfa</th>
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</thead>
<tbody>
<tr>
<td>Crude Protein</td>
<td>&gt;22%</td>
<td>29.7</td>
<td>21.9</td>
</tr>
<tr>
<td>NDF</td>
<td>&lt;34</td>
<td>28.5</td>
<td>37.5</td>
</tr>
<tr>
<td>ADF</td>
<td>&lt;27</td>
<td>26.7</td>
<td>33.9</td>
</tr>
<tr>
<td>TDN</td>
<td>&gt;62</td>
<td>70.1</td>
<td>62.4</td>
</tr>
<tr>
<td>RFQ</td>
<td>&gt;180</td>
<td>222</td>
<td>155</td>
</tr>
</tbody>
</table>

Chart showing the difference in forage tests between optimal 'supreme' tests for alfalfa, Indreland biological treatment and the control receiving NPK fertiliser.

**WHY MONITOR?**

Benchmark: Know where you are starting from: Are your management objectives taking you forward or backwards? Identify early warnings.

Manage: Take action in response to indicators; Guide management of livestock and apply nutritional sprays or bio-controls.

Evaluate: When management strategy changes are needed to better meet identified objectives.

Record: Provide a record of environmental and resource conditions, events and management practices.

Inform: Provide information to inform management; grazing choices; species suitability; water management; Are bio-stimulants or fertilisers providing bang for their buck?

Warn: Early warning for practices which are declining soil health.

Track: Track changes overtime; provide a record that can help to secure leases, partnerships or investment.

Proof: As your ‘smug’ test to put your money where your mouth is!

Long-term monitoring for soil carbon is typically repeated on a 4 to 5-year basis. More dynamic measures like Brix and temperature can be carried out quickly through the season.

See Appendix for what other soil and plant benchmarking tests you can take.
# Chapter 11 Read Your Weeds

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Units</th>
<th>Ryegrass</th>
<th>Capeweed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>N %</td>
<td>2.57</td>
<td>2.18</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>P %</td>
<td>0.21</td>
<td>0.24</td>
</tr>
<tr>
<td>Potassium</td>
<td>K %</td>
<td>2.39</td>
<td>2.30</td>
</tr>
<tr>
<td>Sulfur</td>
<td>S %</td>
<td>0.18</td>
<td>0.18</td>
</tr>
<tr>
<td>Calcium</td>
<td>Ca %</td>
<td>0.46</td>
<td>1.43</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Mg %</td>
<td>0.24</td>
<td>0.32</td>
</tr>
<tr>
<td>Sodium</td>
<td>Na %</td>
<td>0.16</td>
<td>1.17</td>
</tr>
<tr>
<td>Copper</td>
<td>Cu mg/kg</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Zinc</td>
<td>Zn mg/kg</td>
<td>16</td>
<td>27</td>
</tr>
<tr>
<td>Manganese</td>
<td>Mn mg/kg</td>
<td>47</td>
<td>59</td>
</tr>
<tr>
<td>Iron</td>
<td>Fe mg/kg</td>
<td>60</td>
<td>88</td>
</tr>
<tr>
<td>Boron</td>
<td>B mg/kg</td>
<td>4</td>
<td>39</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>Mo mg/kg</td>
<td>0.5</td>
<td>0.4</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Co mg/kg</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Crude Protein</td>
<td>Ratio %</td>
<td>16.1</td>
<td>13.6</td>
</tr>
<tr>
<td>Nitrate</td>
<td>N mg/kg</td>
<td>62.6</td>
<td>133</td>
</tr>
<tr>
<td>Ammonium</td>
<td>N mg/kg</td>
<td>686</td>
<td>407</td>
</tr>
</tbody>
</table>

*Table: Plant tissue tests comparing weed and preferred grass – rye.*
The diagram illustrates the ecological succession and disturbance level. At the highest disturbance level, the vegetation includes:

- Bare Rock
- Lichens mosses
- Scrambling annuals
- Tap rooted forbs
- Annual grass
- Perennial grasses
- Shrubs "woody weeds"
- Shade intolerant trees
- Shade tolerant trees

At the lowest disturbance level, the vegetation includes:

- Bacterial dominated
- B:F 1:1
- Fungal dominated
Prospect Farms during Summer 2018, native C₄ Setaria grass growing in the furrows where vermiliquid was applied at seeding with a cash crop.
Graph showing the difference in herbicide resistance to glyphosate and trifluralin after 3 years. Prospect use the seed from biologically treated soils vs seed which had never been treated with their programme.

**Cultural weed control methods**

- Cross graze other livestock species.
- Train livestock to eat weeds. There are great resources developed by Dr Fred Provenza on the Utah State University website www.behave.net.
- Inoculate seeds with compost/vermicast extracts or packaged biologicals to support crop health.
- Biocontrol agents: fungi, bacteria and insects that will target pest plants.
- Mow under trees or vines. Add more low-growing companion species.
- Address the key drivers for weed germination and lift soil health to set the scene for what you want to grow.
Chapter 12 Good Bug, Bad Bug?


**Correlation between Brix and insect pressures from 22 properties in the Hawke’s Bay and Manuwatu regions in New Zealand. Florent 2001**
The plant signals to the trichoderma fungi (on right), to provide the trigger. The fungi release an oxidative burst which sets off a cascade of defence network: jasmonic (JA), abscisic (ABA) and salicylic acids (SA). Without these microbial relationships, the defence network is disabled and diseases, such as botrytis, run rampant (left side leaves in image).

Strategies to reduce insect pests

* Diversity, diversity, diversity!
* Cover crops, intercropping, wild field margins, crop rotations, alley crops, mosaic of diverse crops. Feed a diversity of soil microbes and beneficial insects.
* Increase Brix level.
* Reduce soluble nitrogen use.
* Reduce disturbance.
* Reduce free amino acids and plant stress.
* Consider if this is the right crop for my environment?
* Increase your observation skills around natural insect dynamics.
* Opt for biological seed treatments to increase elicitor responses.

Biocontrols in transition

If using bio-pesticides during the transition, use with the following application considerations:

* Evening applications are preferable, as many pollinators are resting and spores are inactivated by sunlight.
* Mix and apply with fish hydrolysate.
* Need to be applied during larval stage of the pest life cycle.

Note: biological inoculums do not tank-mix with fungicides, or trace elements such as copper or zinc. To optimise pest reduction, keep a focus on the soil health principles.
Chapter 13 The Future is Now

(a)

Achieving goals without changing environment

Activation energy required

(b)

Achieving goals by changing environment

Less activation energy required
Appendix

Transitions

The drivers for change for many producers in this book were inspired by an epiphany. However, you could wait your whole life for one of those. If the actions of the regenerators are new or daunting to you, then here are some potential steps to build confidence.

1. **Start with something ridiculously small.**
   If your concerns about risk have you sitting on the fence, set yourself up for success. Plant just a few trees. If you plan to spray for weeds, have fulvic acid ordered and sitting next to the herbicide. Try putting seeds in with your livestock mineral. Alternate a fungicide with a nutritional spray. Trial one pasture with heavier animal density and then miss it from your next rotation. Swap chemical seed
treatments with a biological seed treatment. Add humic/humates to your nitrogen and drop by 30% in an area.

2. Shift your environment.
When it comes to transforming our thoughts and actions, our catalyst is the environment. We can shift the environment around us in such a way, that taking action requires less motivation and willpower (activation energy). Surround yourself with regenerative producers and create a discussion group, “biological barbeque.” Read magazines and books.

3. Regenerate your thinking processes.
It is the stories that you believe or tell yourself, that give you actions or prevent you from learning. The only way to really shift our actions, starts with who we see ourselves as ‘being’, or our mindset about who we are. This ‘being’ then informs our thoughts, our language and our habits. It’s important to focus on the right steps, versus the right result. Completing personal and professional development programmes, are critical steps to reveal potential “blind spots” for action. I’m a big advocate for Ranching or Grazing for Profit Schools in North America and Australia. And if you really want to get to the bottom of your own life story, Landmark Worldwide offers training across the planet.

4. Get out of nature’s way!
The key to regenerative agriculture is not the answers, but the quality of the questions we ask. One excellent habit to develop, is to ask the ‘why’ question at least 6 times, like; “Why are you calving in the mid of Winter? Why are you cutting hay? Why are you using that insecticide, or growing a crop in an unfavourable environment?” I am amazed at how often the last answer becomes “because that’s how we’ve always done it.” Asking these why questions and then taking action, can be the most profitable exercise you could ever undertake.

Ask the question; “How would this work in nature?” For instance, “When are the wildlife having their babies? How does this tree or vine grow in the wild? How can we align our practices with nature’s basic rules?” The further we stray, the bigger the costs. Some of the most powerful actions we can do to regenerate land, are to stop doing the things that are causing harm or working against the sync of nature.

5. Have patience dear friend.
This may be the most challenging aspect, for those accustomed to the rapid hit from chemical inputs. How long has it taken to degrade your land resource? The changes in the soil, may happen long before benefits may be visible above ground. Humans by nature are impatient, but if we dig up a seedling to see if it has germinated, we undermine its progress. Just trust the seed is growing and visible changes are coming. Monitoring soil health, infiltration, plant tissue tests and working alongside a mentor, helps to alleviate your concerns. There is a certain degree of faith and trust applied in the transition. Understanding the “unintended consequences” of the quick fix and the breakdown that is occurring at every level of our current modern farming model, can help steady our focus. The science is there, consumers are waiting and the political awareness and will for action is now bubbling up.
Transition steps

Avoid costly production losses by building on local knowledge: Mentor; consultant, a successful farmer, or join a discussion group. Do your own trials.

Education: Books, courses, workshops, podcasts...

Benchmark: Measure where you are now; soil mineral, biology, carbon, leaf tests and photos. Hone your observations.

First do no harm: Reduce and then eliminate products that blow the microbial bridge; soluble N and P, herbicides, fungicides. Buffer chemicals with microbial foods.

Triage and address major limitations: Sunlight capture, air, water, decomposition and minerals.

Encourage biodiversity above and below ground: Herbal leys, fodder crops, cover crops, shelter belts, inter-planting. diversity, diversity, diversity!

Implement practices: Increase photosynthesis, rooting depths and soil carbon. Avoid bare soil at all times.

Apply broad-spectrum products: Feed biology and address major nutrient deficiencies, i.e. Lime, rock phosphate, guano, seaweed, fish, seawater, compost, vermicast, sugar etc.

Health: Ensure crop and animal health needs are met; if not, use free choice minerals, probiotics etc.. Test quality of your produce.

Monitor and observe changes: Brix, EC, pH, photographs. Adjust programme if required.

Strategic long-term planning: Land and stock use choices. Focus on business resilience.

When you can see your successes, mentor others!

These tips were created from brainstorming sessions with over 300 regenerative farmers, growers, researchers, educators and support companies during the Association of Biological Farmers National Roadshow with Dr Christine Jones, June 2010.

Using a refractometer

A refractometer measures degrees, or %, Brix – the dissolved solids and the sugars produced during photosynthesis.

It takes less than a minute to give you a reading of the status of your crops. Measuring plant sap Brix across several samples in a crop, gives an immediate insight into the general health of that crop. Take multiple readings consistently, at the same time of the day, from the same part of the plant (then ensure all subsequent readings follow suit). Record your findings and compare the trends! Start a habit of recording as often as possible, while you build a picture of your land.

Brix levels will change through the day, starting lower in the morning, peaking early to mid-afternoon, before dropping with the sun. This is consistent with the daily plant growth cycle and the
absence or presence of sunlight. Generally, optimal health and quality for grasses, is indicated by a reading above 12° and for most legumes, above 14°.

Brix can help determine the suitability of a foliar spray.

Methodology:
Measure Brix on a crop, before a foliar spray application and on a control area with no application to be applied. Re-test both areas, 1-24 hours after application of different foliar sprays.

Brix levels need to lift by at least 2 points above the control to be considered suitable for application. If it remains the same or drops, then re-test the Brix level in one week. If the Brix level is still low after a week, then it’s reasonable to conclude, that the application of these inputs, are not effective at this time. Use the 5M approach to reconsider what may be the limiting factors. Mindset, Management, Microbes, Minerals and OM.

Operating Instructions

1. Calibrate refractometer using pure, distilled water

2. Open the daylight plate, wipe the refraction prism carefully with soft flannelette. Be careful not to scratch the surface.

3. Choosing the fully developed leaves, twist the leaves a few times and then place into the well of a good quality garlic crusher (Jumbo Zyliss) (if sampling low sap species like avocados and grapes use sap vice grips).
4 Squeezing out the sap. (If plant material squeezes out of the crusher—place a coin in the bottom of the well). Put 2-3 drops of sap on the prism surface.

5 Cover the daylight plate slowly to let the solution cover the whole prism surface reducing any air bubbles.

6 Turn the refractometer towards a light source or bright place.

7 Look through the lens. Turn the focus adjustment until the graduated lines can be seen clearly.
MORE ON BRIX

Brix levels can vary due to stress and/or dehydration and once plants set flower/seed. Therefore, it is vital to keep good records and monitor changes in Brix level over time and to avoid sampling insect or disease damaged leaves.

The method of extracting sap can have a large influence on the reading.

Generally, Brix readings will drop with low atmospheric pressure e.g. the onset of a storm.

Analyse your weeds! The sap of weeds should have a lower Brix level than the crop. If this is not the case, you need to look at why your current management is favouring weed production. If Brix is higher in your weeds, you may need to intervene to reduce the threat of yield reductions. If the Brix level is lower in the weeds, you do not need to step in, as the crop will out-compete them in time.

The lower the humus levels in soil, the faster the Brix level will drop following prolonged cloudy or rainy periods. In these conditions, to prevent Brix level dropping quickly use a foliar spray of fulvic acid.

Brix levels should be uniform when sampled throughout the plant; if not, then suspect a soil imbalance. P:K ratio is a key suspect here.

Brix levels track the intensity of the sun, so are lower in the morning than afternoon. If Brix remains stable through the day, then suspect boron deficiencies. This critical trace mineral is responsible for translocating sugars between roots and leaves.

As with all testing, Brix levels need to be weighed up with other tools and good observations. It is not a tool to use in isolation.

Take good records, during any single day and across the season, to get a true picture of your crops.
Infiltration Test

1. Place a piece of wood over the top of the ring. Strike the board with the hammer until the ring is driven into the ground to the 100mm mark. If the soil is very dry and compacted or rocky, then use the knife to cut a slit into the soil for the ring, whilst disturbing the soil as little as possible.

2. Line the soil surface inside the ring with a sheet of plastic wrap to completely cover the soil and ring. This procedure prevents disturbance to the soil surface when adding water.

3. Insert a ruler and add 25mm (1 inch) water.

4. Slowly pull the plastic sheet away and start your TIMER. When the last bit of water disappears check the time again and see how many seconds / minutes it took for 25mm of water to soak in. Using the same ring, repeat Steps 2, 3 & 4 a further 2 times. Record the time elapsed for each infiltration measurement. All of the tests should be conducted consecutively.
If you conduct multiple tests and they produce the same result, this result is most likely an accurate estimate of the saturated infiltration rate.

**Infiltration considerations:**

If soils are saturated, wait a few more days for the soil to dry out.

If you capture an additional 25mm rain, it can mean 1/2 ton/ha (500lbs/ac) in extra yield.

If the soil surface is uneven inside the ring, count the time until half of the surface is exposed and just glistening.

The moisture content of the soil will affect the rate of infiltration; therefore, two or three infiltration tests are usually performed (if soil is dry). The first inch of water wets the soil and the second inch gives a better estimate of the infiltration rate of the soil.

Even a high-quality soil, will eventually break down after several storms. The aim is to improve soil structure to maximise infiltration and minimize run-off.

**Monitoring Indicators**

<table>
<thead>
<tr>
<th>Soil indicators</th>
<th>Plant indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil structure/ porosity</td>
<td>Sap Brix/EC/pH</td>
</tr>
<tr>
<td>Colour and # of mottles</td>
<td>Plant growth</td>
</tr>
<tr>
<td>Soil Colour/carbon</td>
<td>Plant diversity</td>
</tr>
<tr>
<td>Earthworms/dung beetles</td>
<td>Legumes (nodules red)</td>
</tr>
<tr>
<td>Soil smell/taste?</td>
<td>Weeds/pests/disease</td>
</tr>
<tr>
<td>Infiltration rates</td>
<td>Plant colour</td>
</tr>
<tr>
<td>Water holding capacity</td>
<td>Urine/manure patches</td>
</tr>
<tr>
<td>Surface relief</td>
<td>Pasture utilisation/palatability</td>
</tr>
<tr>
<td>Temperature</td>
<td>Rhizosheath development</td>
</tr>
<tr>
<td>Penetrometer (compaction)</td>
<td>Root length and root density</td>
</tr>
<tr>
<td>Soil pH, EC (electrical conductivity)</td>
<td>Area of bare ground</td>
</tr>
<tr>
<td>Soil mineral tests</td>
<td>Drought stress</td>
</tr>
<tr>
<td>Soil biological testing</td>
<td>Input costs to maintain production</td>
</tr>
<tr>
<td>Enzyme activity</td>
<td>Plant tissue tests: minerals, RFV, ADF,</td>
</tr>
<tr>
<td></td>
<td>Crude Protein...</td>
</tr>
<tr>
<td>Respiration</td>
<td>Storability and digestibility</td>
</tr>
<tr>
<td>Fungi:Bacterial ratios</td>
<td>Near infrared spectroscopy</td>
</tr>
<tr>
<td>Mycorrhizal colonisation</td>
<td></td>
</tr>
<tr>
<td>Biological diversity</td>
<td></td>
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</tbody>
</table>
Growing Mycorrhizae

Make your own mycorrhizal inoculant – combine potting mixes with root materials collected from plants in local healthy ecosystems. Grow AMF spores in this potting mix using C4 grasses, such as Sudan grass, Paspalum spp, Corn etc.

FIND A HOST

DIG IT UP

BREAK IT UP

CUT IT UP

HARVEST TRAP CULTURE IN 4 MONTHS
Transition Weed Strategies

Brewing weed teas

Fill a drum with your troublesome weed, place a heavy weight on top of the weed and slowly let them stew in their own juices. If the plant contains high cellulose or lignin, then you’ll need to add some water to help it break down. Have a tap on the bottom of the drum and extract the liquid to spray onto heavy infestations. Sometimes we’ve seen extraordinary results and then other times nothing!

Trial different rates from a few 100mls to 20 litres/Ha (2 gal/ac). My thinking is you’re breeding up the bugs that like to eat your weed and you’re also concentrating the trace elements that this weed has been accumulating. (Thanks to Steve Erickson for this recipe.)

Brewing allelopathic chemicals--harvest mature plants with known suppressive chemicals, such as Forage radish, Sorghum, Sunflower or Mulberry. Dry and chaff these plants before soaking them in unchlorinated water for 24 hours. Filter the liquid and apply as you would with a herbicide. Results have shown this method can be more effective than chemical controls. You’ll need a lot of plant materials for this, around 25kg/ha (lbs/ac).

Buffer non-residual herbicides by 30% and add 1 part fulvic acid to 4 parts herbicide. (Note: Not all herbicides mix with fulvic acid: jar test first).

Weed Indicators

<table>
<thead>
<tr>
<th>Bare soils</th>
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<tbody>
<tr>
<td>Scrambling fumitory (<em>Fumaria muralis</em>), Purslane (<em>Portulaca oleracea</em>),</td>
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<tr>
<td>Hedge mustard (<em>Sisymbrium officinale</em>), Field bindweed (<em>Convolvulus arvensis</em>)...</td>
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<table>
<thead>
<tr>
<th>Low organic matter</th>
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<tbody>
<tr>
<td>Catsear (<em>Hypochaeris radicata</em>), Cape daisy (<em>Arctotheca calendula</em>),</td>
</tr>
<tr>
<td>Hawkweed (<em>Hieracium caespitosum</em>), Cheatgrass (<em>Bromus tectorum</em>),</td>
</tr>
<tr>
<td>Yellow alyssum (<em>Alyssum alyssoide</em>), Spotted knapweed (<em>Centaurea stoebe</em>),</td>
</tr>
<tr>
<td>Leafy spurge (<em>Euphorbia esula</em>)...</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Compaction or surface crusting weeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dock (<em>Rumex spp</em>), Canadian thistle (<em>Cirsium arvense</em>), Buttercup (<em>Ranunculus repens</em>), Wild chamo...</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nitrate and release-valve weeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clubmoss (<em>Lycopodium</em>), Pennyroyal (<em>Mentha pulegium</em>) and Sedges and Rushes...</td>
</tr>
</tbody>
</table>
Capeweed, (Arctotheca calendula), Black nightshade (Solanum nigrum), Kochia (Kochia scoparia), Nettles (Urtica dioica), Fat hen/Lambsquarters (Chenopodium album), Foxtail barley grass (Hordeum jubatum), Russian and Milk thistle (Silybum marianum)…

<table>
<thead>
<tr>
<th>High available potassium and low phosphorus</th>
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</thead>
<tbody>
<tr>
<td>Many broadleaf weeds: Dandelions (Taraxacum), Common plantain (Plantago major), Scotch thistle (Onopordum acanthium), Tansy mustard (Descurainia pinnata), Wild radish (Raphanus raphanistrum), Common purslane (Portulaca oleracea), Nightshade (Solanaceae), St. Johnswort (Hypericum perforatum) and Inkweed (Phytolacca octandra)…</td>
</tr>
</tbody>
</table>

| Early successional bacterial species: | Foxtail barley (Hordeum jubatum), Quack/Couch (Elymus repens), Wild oat (Avena fatua), Cheat grass (Bromus tectorum), Barnyard grass (Echinochloa), Johnson (Sorghum halepense), Kikuyu (Pennisetum clandestinum), Medusahead Rye (Taeniatherum caput-medusae). |
|--------------------------------------|

| Allelopathic plants: | Water hyacinth (Eichhonia crassipes), Garlic mustard (Alliaria petiolate), Knapweed (Centarea stoebe), Kochia (Kochia scoparia), Black walnut trees (Juglans nigra), Sorghum (Sorghum bicolor), Mulberry (Morus) and Ryegrass (Lolium)… |
|---------------------|

<table>
<thead>
<tr>
<th>Fungal, or ‘sleepy’, soils</th>
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<tbody>
<tr>
<td>Blackberry (Rubus spp), Wild rose (Rosa spp), Poison Oak (Toxicodendron diversilobum), Hemlock (Conium maculatum), Foxglove (Digitalis), Hollyhock (Alcea rosea), Hawkweed (Hieracium), Hemlock (Conium maculatum), Bloodroot (Sanguinaria canadensis), Wormwood (Artemisia absinthium), Mullein (Verbascum spp), St. Johnswort (Hypericum perforatum), Houndstongue (Cynoglossum officinal), Matagouri (Discaria toumatou), Bracken (Pteridium spp), Gorse (Ulex), Broom (Cytisus scoparius), Rabbitbrush (Chrysothamnus spp), Sagebrush (Artemisia spp), Willow (Salix spp), Sweet briar (Rosa spp), African Boxt horn (Lycium ferocissimum) or Mesquite (Prosopis spp).</td>
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</tbody>
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<thead>
<tr>
<th>Non-mycorrhizal</th>
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<tbody>
<tr>
<td>Disturbed habitats, with low competition with other plants and high soil phosphorus; for example, Amaranthaceae, Brassicaceae, Caryophyllaceae, Chenopodiaceae, Polygonaceae and Urticaceae.</td>
</tr>
<tr>
<td>Cyperaceae (Sedges); Juncaceae (Reeds); Brassicaceae (Fanweed, mustard, Kochia, Shepherds’ purse); Amaranthaceae (Pigweed, Beets, Spinach, Lamb’s quarters, Quinoa. Russian thistle or tumbleweed (Salsola tragus); Urticaceae (Stinging nettle); Lupinus (Lupins) and Proteaceae (Macadamia, Bottlebrush).</td>
</tr>
<tr>
<td>In P-limited environments, species have evolved specialized P-mining roots without MF, including Cyperaceae, Haemodoraceae, Proteaceae and Restionaceae.</td>
</tr>
<tr>
<td>As a general rule, if a plant is carnivorous, lives in water, or is a parasite in a tree, it has evolved without a mycorrhizal relationship.</td>
</tr>
</tbody>
</table>
New Zealand born Nicole Masters, is an independent agroecologist, systems thinker, author and educator. She has a formal background in ecology, soil science and organizational learning studies in New Zealand. Nicole is recognized as a knowledgeable and dynamic speaker on the topic of soil health.

Her team of soil coaches at Integrity Soils, have a proven record working alongside food and fiber producers across the U.S., Canada, Australia and New Zealand, taking ag businesses to the next level in nutrient density, profitability and environmental outcomes.

Nicole has worked closely with a wide range of production sectors from; dairy, sheep & beef, viticulture, compost, nurseries, market gardens, racing studs, lifestyle blocks to large-scale cropping. Working alongside such diverse clients, has fostered a broad understanding of the challenges facing different production systems. She has devised and delivered educational programs for varied organisations; consultants, businesses, land care and extension services.

Nicole is one of a growing number of people who are facilitating the rapidly expanding world of quality food production and biological regenerative economies.

Nicole is currently based in North America, travelling with her horse and trailer. Her team at Integrity Soils are available for workshops, team training, facilitation, conferences and keynote presentations. Get in touch:

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