ECO VINEYARDS
GROWING RESILIENCE NATURALLY

FIELD GUIDE

NUTRIENT-DENSE PLANTS ARE MORE RESISTANT TO PESTS AND DISEASES

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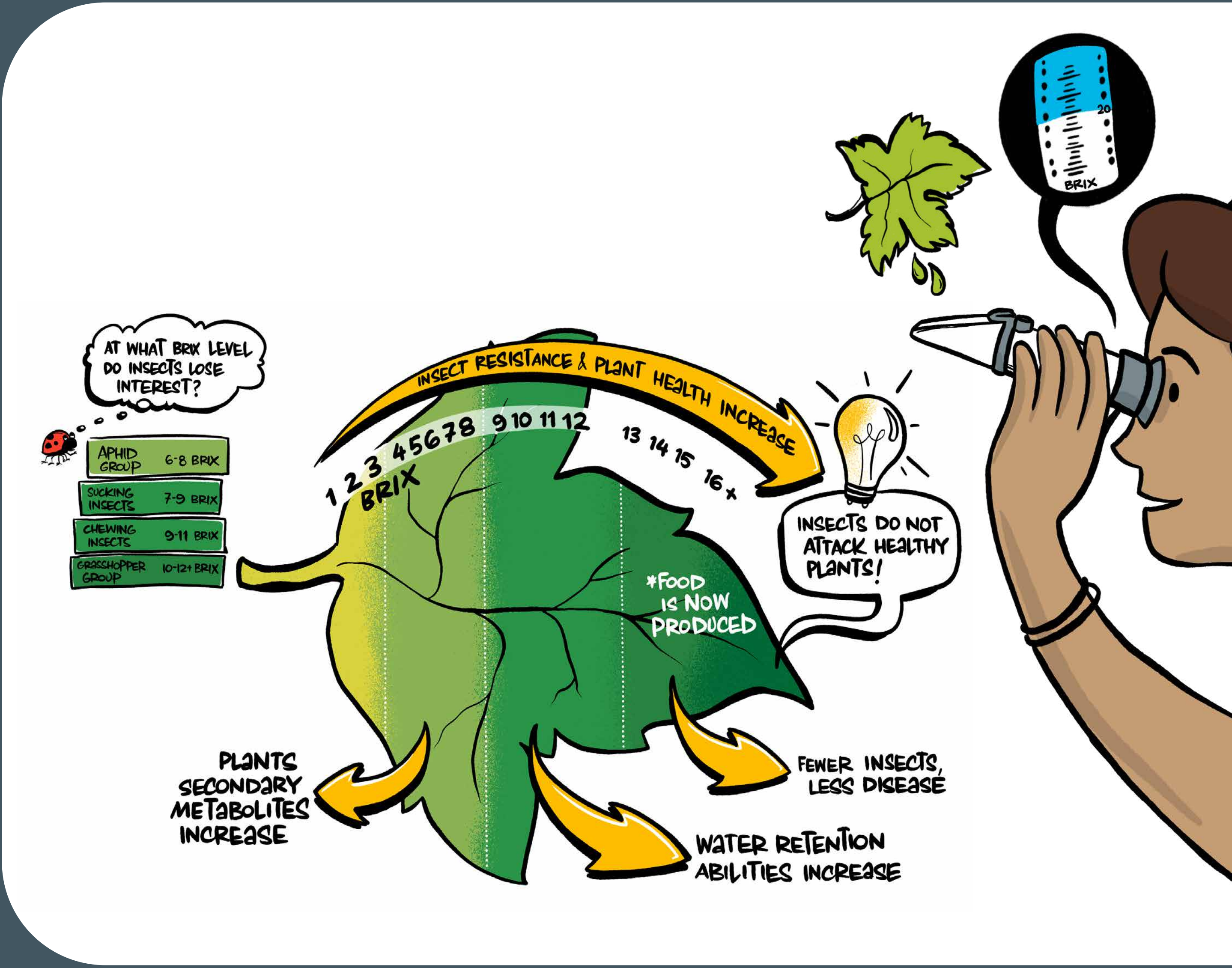

Wine Australia
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DRIVERS OF GRAPEVINE HEALTH

In this field guide we explore the relationship between plants, nutrients, microbes and their environment. Including some of the ways you can objectively assess plant health, and the interactions between grapevines and common insect pests and diseases.

We present some historial thinking on this subject which provides the foundation for more recent insights including the plant health pyramid, which supports the link between plant nutritional integrity and potential susceptibility to pathogens.

In viticulture, as in nature, a healthy agroecosystem is most easily achieved in environments which have a richness (diversity) of species (including predators) and a balance of nutrients in the right form.

A diversified production system is better able to maintain its equilibrium through the multiple relationships which exist between biotic and abiotic components.

The challenge of maintaining agricultural productivity encourages growers to apply soluble nitrogen fertilisers to promote vine growth and pesticides to protect yields. This can create an unbalanced and unhealthy system.

Interestingly, pest and disease population growth are often strongly dependent upon acquisition of nitrogen-resources (e.g., amino acids) from crop tissues, and concentrations of these compounds depend on the metabolic state of the crop, its growth stage, environmental conditions, and agrochemical inputs (Martinez et al., 2021).

Functional biodiversity and biocontrol are just two parts of a complex puzzle

It may take several years for a healthy agroecosystem to become capable of regulating pests and pathogens through biological control mechanisms. However, as we explore below, an integrated pest management (IPM) approach does not fully explain the dynamics between plants and pathogens.

The concept of economic thresholds which states that insect pests only need to be treated when they exceed a certain population level, theoretically should have reduced insecticide inputs. However, after 50 years, the verdict is - that integrated pest management (IPM) did not fully deliver on its promises and the use of chemical inputs is at an all time high. A central problem with IPM as it is currently practiced is that it assumes that pests are inevitable (Lundgren, 2022). We will challenge this assumption below.

"*Insect pests aren't an entomology problem. Insect pests are a soil problem. They are a problem of a system devoid of life. But most of all, insect pests are a cultural problem.*" **Dr Jonathan Lundgren, Ecdysis Foundation.**

Figure 1. [L to R] Economically damaging insect pests of grapevines include *Calepitrimerus vitis*, rust mite; *Phalaenoides glycinae*, grapevine moth larva; *Epiphyas postvittana*, light brown apple moth (LBAM) larva inside a developing bunch of grapes [Photos: Mary Retallack].

Are we overlooking key components of plant health and insect interactions

Interestingly, Rowen et al. (2022) found that the best pest management outcomes may occur when biological control is encouraged by planting ground covers and avoiding broad-spectrum insecticides as much as possible.

Moreover, ground covers along with no-till and a reduction or abandonment of pesticides, do a lot more than increase the number of predators in a production system. In addition, ground covers alter the microbial communities found in association with the focal crop i.e. grapevines, potentially leading to altered symbioses that keep herbivores in check. The science is clear that plant diversity, ground cover, and minimal disturbance to the soil are inherent in pest suppression (Lundgren, 2022).

> "*Insect behaviour is deliberate and designed to eliminate weak, unformed, nutritionally deficient, unbalanced plants.*" **Dr Arden Anderson**

DIS-EASE

It is widely accepted that pests and diseases attack weaker plants, not healthy ones and there are several reasons for this including the molecular structure of plants (sugars, carbohydrates, secondary metabolites) and plant chemical signals.

Moreover, routine applications of pesticides and/or nitrogen-fertilisers may inadvertently reinforce the problem of pests and disease damage on crops by enhancing the nutritional quality of crops that is suited for these organisms (Datnoff et al., 2007; Martinez et al., 2021).

> "*Insects are nature's garbage collectors, and diseases are her cleanup crew.*" **Dr William A. Albrecht, University of Missouri**

Trophobiosis

Trophobiosis is derived from two Greek roots - *trophikos* (nourishment) and *biosis* (life).Trophobiosis is a symbiotic association between organisms where food is obtained or provided. The provider of food in the association is referred to as a trophobiont.

For example, several ant genera are recorded as tending groups of insects from the order Hemiptera, i.e., scale, mealybugs, and leaf hoppers. In most cases the ants collect and transport the honeydew secretions from the hemipterans back to the nest for consumption. In mutualistic relationships, the production of honeydew by trophobionts is rewarded by protection from a variety of predators by the attendant ants.

> "*The relationships between plant and parasite are primarily nutritional.*" **Francis Chaboussou, INRA**

Trophobiosis in pest and disease control

A similar analogy can be used for plants and their relationship with pests and diseases. Studies done by the French researcher Francis Chaboussou who was an agronomist at the National Institute of Agricultural Research (INRA) in the 1980s provides the basis for the theory of trophobiosis, which states that the susceptibility of a crop plant to pests and diseases depends on its nutritional state.

> "*Pests and diseases will not attack a healthy plant, a pest starves on a healthy plant.*" **Jose Lutzenberger, former Minister for the Environment, Brazil**

The health of a plant is directly associated with its internal balance, which is constantly changing. According to Chaboussou (2004) it is not just any plant which is attacked by pests and diseases, but only those which could serve as food for the insect or pathogen i.e. the cultivated plant will only be attacked when the food these pests need is available in the sap.

All factors which affect a plant's internal balance and functioning can lessen or increase its susceptibility to pests and diseases including environmental, and management practices such as soil fertility and the type of fertilisers used (Guazzelli et al., 2007; Martinez et al., 2021).

An understanding of trophobiosis can be very useful during the process of transition to agroecological production systems, especially in times of environmental stress (Martinez et al., 2022).

Trophobiosis theory is summarised by (Paull, 2007) as:

- Pests shun healthy plants
- Pesticides weaken plants
- Weakened plants open the door to pests and disease
- Pesticides precipitate pest attack and disease susceptibility, and they induce a cycle of further pesticide use.

According to the trophobiosis theory, it is nutrient deficiencies and imbalances that lead to pest and disease outbreaks, and that synthetic pesticides and fertilisers can cause these deficiencies and imbalances.

Insect resistance or a reduction in plant health?

Pesticides used on crops may lose their efficacy after repeated applications, the pests return and the pesticide dose, or the frequency of application needs to be increased, and/or new pesticides need to be introduced into the spraying regime. Is this an example of insect resistance or a reduction in plant health?

The conventional view is that the pest develops resistance. However, Chaboussou's explanation is that the plants are weakened, and progressively more so, as they are repeatedly assaulted by this chemical warfare. Because they are progressively weakened ever more chemical intervention is required. Hence the pesticide treadmill experienced in chemical farming (Chaboussou, 2004; Paull, 2007). Chaboussou's alternative approach is to focus on the health of the crop.

> "***We need to overcome the idea of 'a battle'; that is, we must not try to annihilate the parasite with toxins that have been shown to have harmful effects on the plant, yielding the opposite effect to the one desired. We need, instead, to stimulate resistance by dissuading the parasite from attacking. This implies a revolution in attitude, followed by a complete change in the nature of research.***" **Francis Chaboussou, INRA**

Moreover, Martinez et al (2021) found that nitrogen-fertilisers enhance the nutritional quality and attractiveness of crops for pests and diseases and they can also alter a plant's expression of the defensive traits (both morphological and chemical) that serve to protect them against these organisms.

Exposure of crops to pesticides (including commonly used insecticide, fungicide, and herbicide products) can result in significant metabolic disruption and, consequently, an accumulation of amino acids within crop tissues which are nutritionally valuable to pathogens.

Plant infra-red signaling

Another aspect of plant and insect interactions is highlighted by Dr Philip Callahan a military researcher who discovered that plants and insects are communicating with each other in the infrared spectrum.

> "***When plants have the right balance of nutrients they don't stand out to insects in the infra-red range. However, if plants have a high amount of ammonia, this enhances the infra-red signal for insects and acts like a neon sign against a dark background.***" **Dr Philip Callahan**

A pesticide will remove pests but doesn't reduce the infrared signal for herbivores (Callahan, 1975; Callahan, 1994; Kempf, 2022). It has long been known that plants which are fertilised with organic material present few pest and disease problems (Martinez et al., 2021). It is also well known that with the modernisation of agriculture, the number of species which are now regarded as pests and diseases has increased (Guazzelli et al., 2007).

Sap sucking insects

In the vineyard, one of the ways we can potentially reduce the impact of sap sucking insects is to objectively increase plant health by ensuring optimal nutritional integrity.

A simple baseline assessment can be achieved by measuring the concentration of Brix found in plant leaf blades and assessed using a manual or electronic refractometer in the vineyard (and followed up by sending a sap sample to the laboratory). As the secondary metabolites and complete proteins produced by the plant increase it is thought that they become less susceptible to pathogens.

Figure 2. Economically damaging pest insects of grapevines include *Parthenolecanium persicae*, grapevine scale (left), and *Pseudococcus longispinus* long-tailed mealybug (right) [Photos: Mary Retallack].

Insect digestive systems

Dykstra (2019) explains that the digestive system of many insects (i.e. grasshopper) is essentially a tube inside a tube, where food is consumed via the mouth, digested in the gut and waste products are excreted at the anus.

However, the digestive system of many Hemiptera insects is unique as it folds back against itself and includes a hindgut with a filter chamber that will accumulate most of the sugars and excrete them as honeydew, so it doesn't overwhelm the digestive system of the insect and kill it (**Figure 3**).

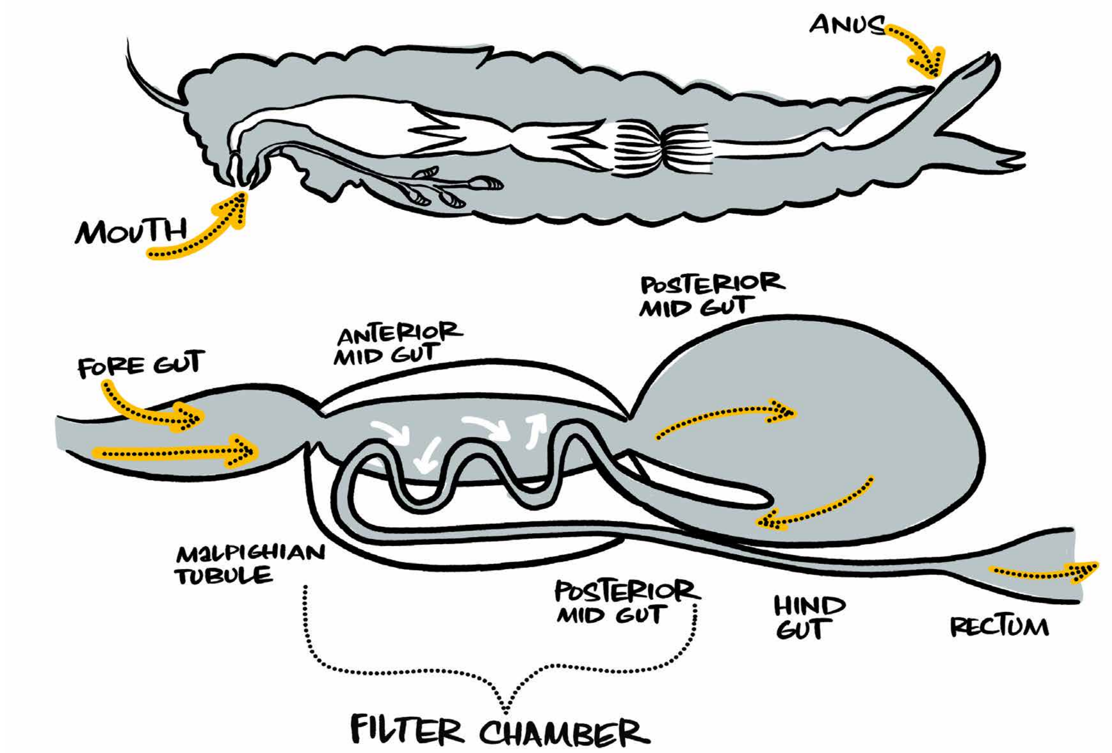

Figure 3. Insect digestive systems of a grasshopper (top) and aphid (below) highlighting the filter chamber of many Hemiptera species [Image: modified from Dykstra, 2019].

Insects have a simple digestive system and cannot digest the same foods that we do. Low-Brix plants are designed for the insect gut. They do not have the digestive enzymes to break down healthy proteins from high-Brix plants, only the broken or incomplete proteins from low-Brix plants (Dykstra, 2019).

This structure allows the insects to ingest and process large volumes of plant sap. Excess water, sugars, and certain amino acids bypass most of the midgut and are shunted directly into the hindgut for excretion.

Scale insects and mealybugs are herbivores from the order Hemiptera. They have piercing and sucking mouth parts that they use to feed on plant sap. However, they are unable to feed on plants with high Brix (sugars) in the leaves (Dykstra, 2021).

It is important to remember that the conversion of nitrogen to amino acids and complete proteins is a complex process that involves plant nitrate first being converted to nitrite. Nitrite is then converted to ammonium. The ammonium is used for synthesis of amino acids, and these amino acids become the precursors of complex plant proteins (Martinez et al., 2021). Synthetic forms of nitrogen fertilisation may increase tissue concentrations of soluble nitrogen and amino acids, as the uptake of nitrogen can occur more rapidly than the plant can incorporate it into primary and secondary metabolic processes.

The insight for viticulturists is that if we can produce grapevines that are optimally photosynthesising with excellent nutritional integrity, that have the time and capacity to produce complete proteins, then these plants are likely to be less interesting, and less susceptible to insect damage from grapevine scale, mealybugs, leafroller moths etc.

A simple way to objectively assess plant health is to assess leaf brix. This is commonly done in broadacre and other crop production systems and is another tool available to viticulturists.

How to assess leaf sap

Many wine grape growers will be already be familiar with using a refractometer to assess berry juice Brix or total soluble solids (TSS) to assess sugars increasing in maturing fruit as it reaches physiological and flavour ripeness.

A refractometer is a scientific instrument that measures the amount that light is bent (or refracted) when it moves from the air into a sample. Refractometers are typically used to determine the refractive index of a liquid sample. The instrument is calibrated in terms of refractive index and usually contains a scale in terms of degrees °Brix.

A common type of refractometer consists of two prisms between which a portion of the test sample is placed. A mirror reflects light through the prisms and test sample. A telescopic tube with crosshairs is superimposed on the field of vision, correlating to a scale calibrated in terms of refractive index, °Brix, or both.

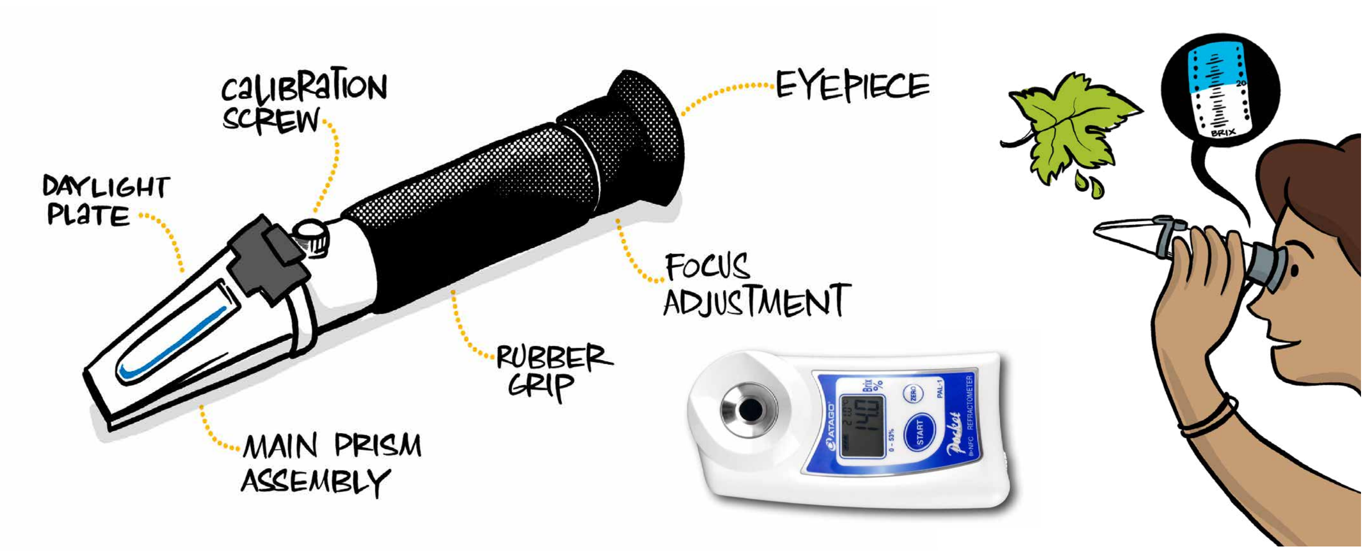

Figure 4. A manual or electronic refractometer can be used to assess leaf and fruit Brix.

How to use a refractometer

The refractometer measures degrees Brix, a measure of the dissolved solids and the sugars produced during photosynthesis (Integrity Soils, 2024).

To analyse a leaf blade sap sample using a manual refractometer:

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

2. Choose the first fully developed leaves, remove the petioles (leaf stalks).

Why do we sample the leaf blades only? They are a nutrient sink whereas the petiole is a nutrient and water transport pipeline, and nutrient levels in the petiole sap can fluctuate by as much as 30-40% at different periods during each 24-hour photocycle (Kempf, 2021).

Twist or role the leaves a few times to break the leaf cells and then place them into the jaws of a pair of modified vice grips (a garlic press may not be strong enough to process grapevine leaves) and then squeeze out the sap.

You may need to reposition the folded leaf blade in the vice grips and squeeze several times to get the sap to flow. It is important to always use the same method.

3. Put two or three drops of sap on the prism surface and then cover the daylight plate slowly to let the solution cover the whole prism surface without any air bubbles.

4. Turn the refractometer towards a light source or bright place. Turn the focus adjustment until the graduated lines can be seen clearly.

The readings of the demarcation line between brightness and darkness indicate the dissolved solids. You can also check the manual reading using an electronic refractometer (and use the same juice sample for a leaf sap pH assessment - more on this below).

The blurrier the line, the better. If the line is sharp between bright and dark, this can indicate free nitrates (especially if below 3 °Brix) and lower food quality.

Figure 5. Leaf Brix can be measured using a pair of modified vice grips to extract leaf sap and a refractometer which provides an objective measure of plant health [Photos: Mary Retallack].

How to measure leaf °Brix – an objective measure of grapevine health

WHAT: °Brix is a measure of the dissolved solids in a liquid and is commonly used to measure dissolved sugar content of an aqueous solution, in this case leaf sap. Although the Brix scale is based on the amount of sugar dissolved in water, Brix is an indirect measurement of the amount of amino acids, proteins, flavonoids, minerals and other nutrients in the sap. Sugar is only one component of Brix.

The refractometer directly measures dissolved solids in plant sap, so it is an indication of your skills as a chlorophyll (or plant photosynthesis) manager.

The following information is paraphrased from entomologist, Dr Thomas Dykstra (2019) who has pioneered much of the work focusing on plant sap Brix and the relationship with insect pests.

These assumptions may require further testing on grapevines to fine tune the recommended Brix ranges. However, they provide an interesting framework for individual wine growers to set a baseline and correlate this with plant health via their own observations as a starting point and following this up by assessing the nutritional integrity of the grapevines via laboratory testing.

Sugar is the main product of photosynthesis. The more a plant photosynthesises, the more sugar is contained in its tissues, and the higher the leaf Brix readings. This sugar is produced in the leaves and is not only stored in the leaves but eventually descends to the roots as well.

Depending on environmental conditions and the health of the plant, approximately 20 to 70 percent of the sugar (photosynthates) is expelled into the soil from the roots. This expelled sugar feeds the microbes that will, in turn, break down minerals and supply them to the plant. Therefore, high Brix plants will support a thriving subculture of microbes in the soil.

WHY: According to Dykstra (2019), high Brix (14 and above) means not just that insects will not attack a given plant but that they will not even be attracted to the plant. In short, pest insects will pass over a high Brix field. The converse is also true. Insects are reportedly very attracted to low Brix plants (6 and below).

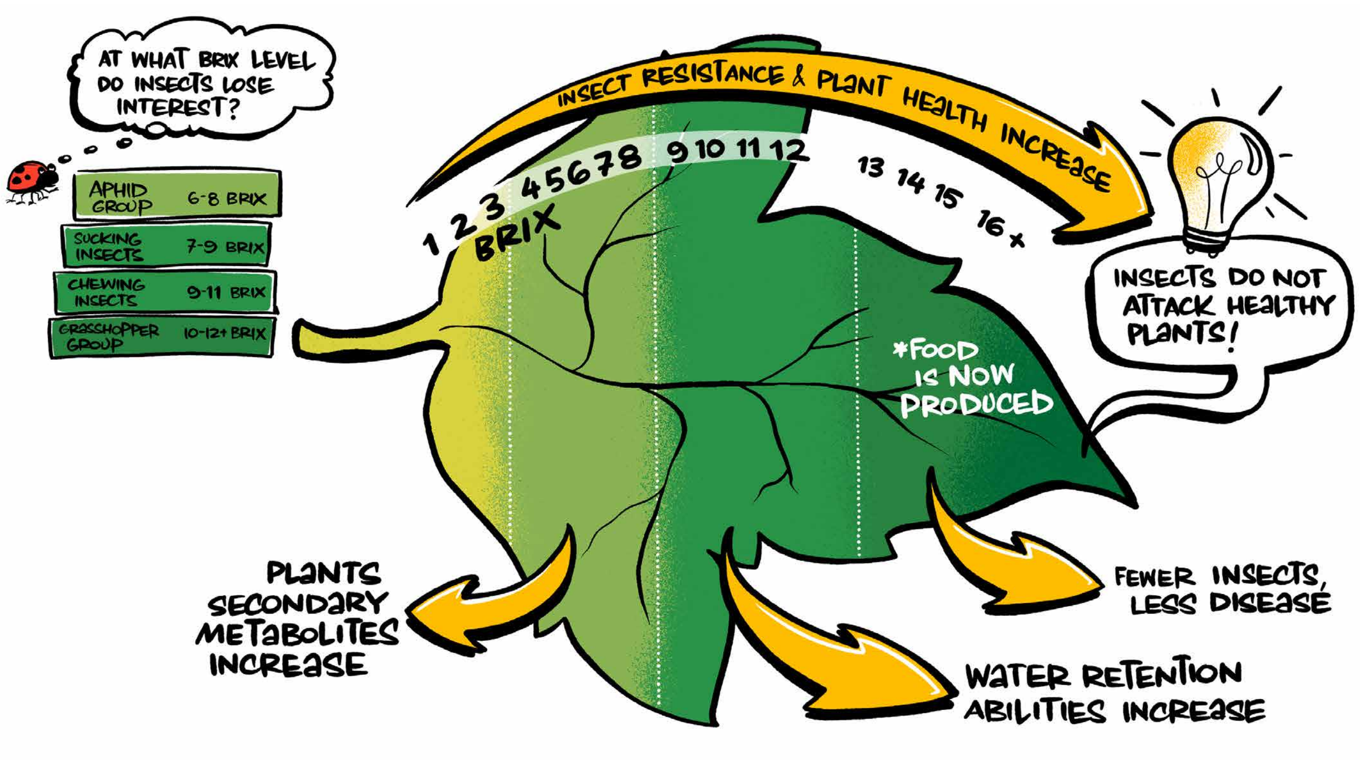

Figure 6. Leaf Brix chart and generalised markers of plant health and resistance to insects and diseases [modified from Dykstra, 2019)].

Interpreting leaf sap Brix measurements

The following information is also paraphrased from Dykstra (2019).

Low Brix plants: 0 to 2

If a fully-grown plant falls between 0 and 2 Brix, insects will move in quickly to consume these plants, and disease will run rampant in these plants since they essentially have no immune system.

Mid-level Brix plants: 3 to 7

The next general category is substantially different. Those plants with leaf Brix readings between 3 and 7 have a fighting chance at survival but they will not thrive. Size, health and yield will all be compromised.

Once most plants reach 6 Brix, there is a significant jump in the production of secondary plant metabolites. Secondary plant metabolites are the phytochemicals that help contribute to a plant's odour, colour and taste.

In addition, some secondary plant metabolites provide natural plant defences against pests. These 6 Brix plants are able to devote their energy reserves into producing new proteins and diverse molecules.

Higher Brix plants: 8 to 11

Once a plant reaches a leaf Brix of 8, the secondary plant metabolites have really started to kick in and natural resistance begins. Some Hemipteran insects, lose interest in the plant that obtains a value of 8 Brix but other insects can and will move in to feed on the plant.

Generally, and although exceptions occur, sucking insects will not tolerate 8 Brix or higher.

Chewing insects that eat the roots or leaves directly, such as caterpillars, grasshoppers, and beetles, will start to lose interest in eating a plant once the plant reaches 10 or 11 Brix.

Higher Brix plants: 12 to 14

Virtually no insects will attack a plant at 12 Brix. However, fluctuations between Brix readings can and do occur throughout a growing season. Even if maintaining Brix levels in each crop, it is not unusual for the leaves to fluctuate 1 to 2 Brix from one week to the next.

Higher Brix plants: 14 to 20+

It is for this reason that the safest place for your plants to be is at 14 Brix or above. In this way, one may be relatively secure that natural fluctuations do not take your crop below 12 Brix where it may become differentially attractive to various insect pests.

Additional benefits of high Brix plants

FEEDING SOIL BIOLOGY: Plants with a Brix of 4 might only contribute 25 percent of their photosynthate to the soil, but plants of 10 Brix may provide the soil with 40 to 50 percent of its photosynthate sugar and still have enough sugar to grow reasonably well.

By the time a plant reaches 14 Brix, there is so much sugar being pumped into the ground from the crop that microbial counts can reach 20 million or higher in a teaspoon of soil.

DROUGHT RESISTANCE: Sugar has another role. It is hygroscopic, meaning that it absorbs water. It may accomplish this by absorbing liquid water, such as from a spill, or by absorbing water vapor from the atmosphere, which can occur under conditions of high humidity. Either way, the more sugar you have in the soil, the higher the soil's water retention. Hence, drought resistance and high-Brix plants go together.

FROST RESISTANCE: Crops with higher sugar contents will also have a lower freezing point and therefore be less prone to frost damage (Tainio, 2021).

Leaf °Brix assessment tips (Integrity Soils, 2024)

- Take Brix readings at the same time of the day (allowing for at least two hours of sunshine in the morning) and preferably from midday to mid-afternoon.
- Take a sample from the same part of the plant (ensure all subsequent readings follow suit) and aim for the first fully unfolded and mature leaf on each shoot.
- Measuring the Brix of a plant's sap gives an immediate overview of the general health of a crop at any stage of production.
- Record your findings.
- Clean and dry the glass prism with water so it is ready for the next test.
- Assess leaf brix fortnightly to monthly. The more sampling effort employed the greater the potential for insights.

What can leaf Brix tell you?

- **Brix can help determine the suitability of a fertiliser mix**. Measure Brix on the crop and a control plant before application, then re-test 1 to 24 hours after input. Brix needs to lift by at least 1 point above the control. If it remains the same or drops, then this input can be considered not suitable at this time.
- **Brix levels can vary due to stress and/or dehydration and once a plant has set flowers/bunches.** This is why it is vital to keep good records and monitor changes in Brix and to avoid sampling insect or disease damaged leaves.
- **Measure your weeds!** Your weeds should have a lower Brix level, if not you need to look at why your current programme is favouring weed production.
  - If the Brix is higher in your weeds than your crop you may need to intervene to reduce the threat of yield reductions.
  - If the Brix is lower in the weeds, you can afford to leave them as the crop will outcompete them in time.
- Brix levels should be uniform throughout the plant, if not then suspect a soil imbalance (check the P:K ratio).

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

- Brix is lowest at dawn, highest after midday, and is affected by in-coming storms and cloud cover.
- Generally, Brix readings will drop with low atmospheric pressure (e.g. the onset of a storm).
- To prevent Brix dropping quickly, use a foliar spray of fulvic acid.
- The lower the humus levels, the faster the Brix will drop following prolonged cloudy or rainy periods.
- Brix should vary through the day as plants move sugars to the roots at night.

Brix needs to be read with other tools and good observations.

Some of the challenges of assessing leaf Brix

The foundational idea is that the refractive index of plant sap correlates to the content of dissolved solids, including sugars, and can be used as an overall assessment of plant health.

When plants reach a certain threshold, they can become resistant to almost all insects and diseases. In principle, this has been demonstrated to be accurate and correct many times, on many farms.

Putting it into practice is tricky though as Brix levels can be exceptionally variable over time, weather conditions, location on the plant, and water availability etc.

For example (Kempf, 2020) explains:

- Brix levels fluctuate through each 24-hour photocycle, usually peaking mid to late day because of accumulated photosynthates.
- In healthy plants with the proper mineral balance for good photosynthate transport, Brix levels often drop 30% or more in the leaves from evening until morning, as sugars are moved to the sugars sinks and used or stored.
- **Brix levels fluctuate based on weather.** Plants can anticipate storms, sometimes by as much as several days, and move all the sugars possible into the roots so they can rapidly recover in case of storm damage. Brix readings should drop quite a bit in advance of a storm.
- **Brix levels fluctuate based on water availability.** Dehydrated crops will have a higher Brix reading because the dissolved solids are more concentrated, but the crop certainly isn't healthy.
- **Brix levels fluctuate at different locations within the plant**. There are often big differences between old leaves and new leaves. It is very common for the leaves most closely associated with the fruit to be the lowest Brix.

  This is true because the fruit often has the highest nutritional requirement and is the last location for nutritional integrity to be achieved. For this reason, we can have disease and insect resistance leaves and susceptible fruit on the same plant.

The location and time with the lowest Brix level determine the degree of insect or disease resistance for the whole crop.

Figure 7. Leaf Brix will often drop prior to a storm [Photo: Mary Retallack].

How to measure leaf pH – and plant susceptibility to insects and fungal pathogens

Another interesting perspective and area of enquiry is that of sap pH. The following information is paraphrased from an article written by Bruce Tainio (and reproduced by John Kempf, 2021) who pioneered the use of plant sap pH as an indicator for disease and insect susceptibility in 1988.

This information is provided for horticultural plants generally and may require additional refinement for grapevines. It is presented here to stimulate thought and further research.

pH represents the percentage of hydrogen ions in a solution including the plant cell or sap.

A change in the pH level of a solution of just one unit equals a tenfold change in the hydrogen ion concentration. If the pH is increased or decreased by two units, the hydrogen ion concentration changes by a hundredfold.

Generally, the mature leaves on the plant will give the most accurate picture of the plant's health, level of resistance or susceptibility to problems. Since the plant spends most of its energy supporting new growth, the pH of new leaves will not reflect the pH of the rest of the plant.

Take a few leaves, roll them up into a tight ball, and squeeze out a few drops of sap using a pair of modified vice grips (they are stronger than a garlic press, which will require more force to extract the sap). This is the same process that is used to assess leaf blade Brix.

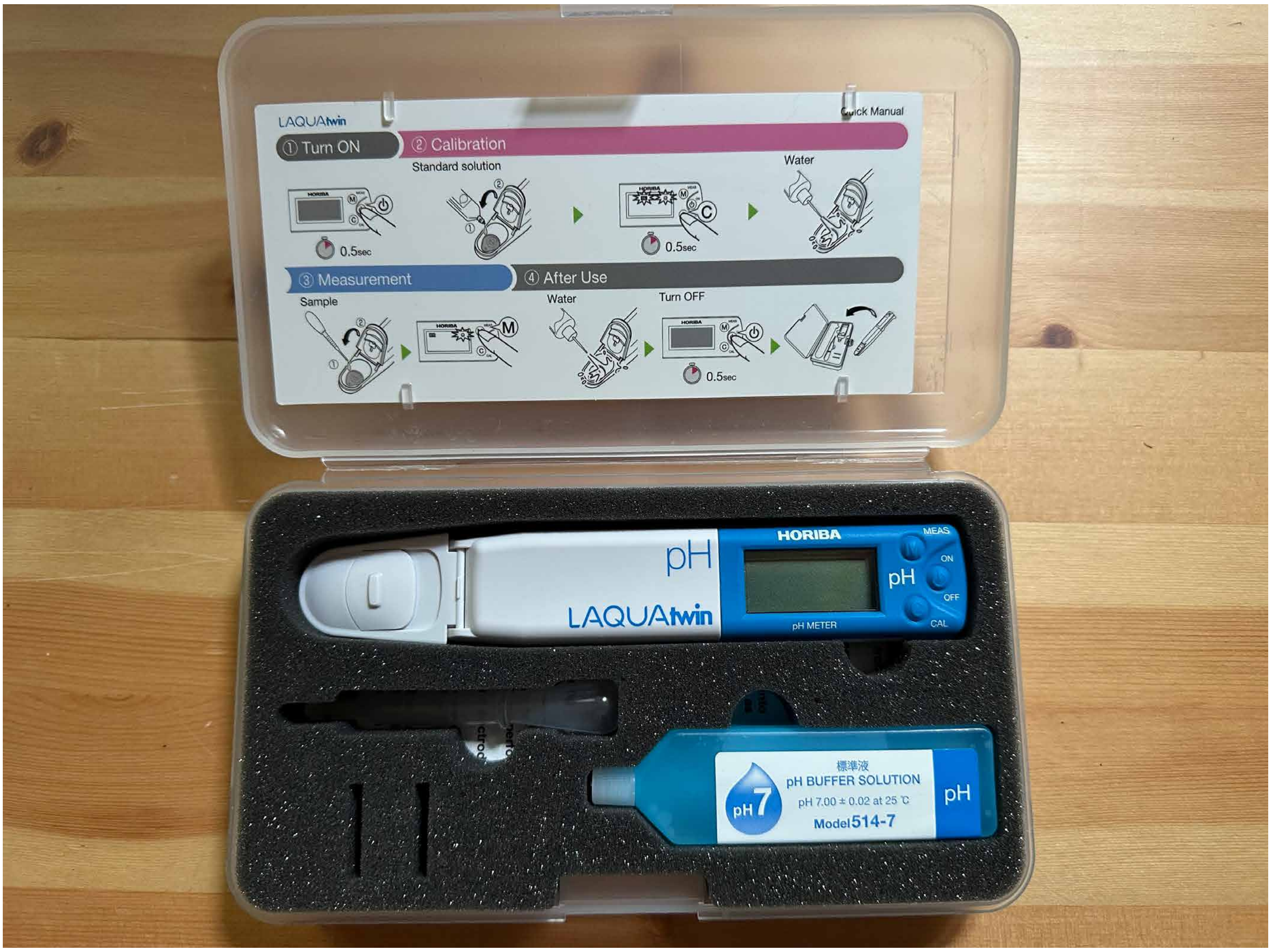

Figure 8. A pH sap meter [Photo: Mary Retallack].

Interpreting leaf sap pH measurements

According to Tainio (2021) a quick plant tissue pH test provides an instant snapshot of the state of health of a plant and can tell us the following information:

- Risk potential for foliage insect attack
- Risk potential for foliage disease attack
- Nutritional balance in the growing crop and quality of nutrition in the fresh fruit crop to be harvested.

For example:

- If sap pH exceeds 6.4, then the most likely cause will be an imbalance of the anions nitrogen, phosphate or sulfur. At pH 8 the likelihood of insect attack is very high.
- Conversely, if sap pH is lower than 6.4, then there is a cation problem, with possible deficiencies of calcium, magnesium, potassium and/or sodium. Low pH suggests fungal problems. At pH 4.5 the probability for fungal attack is very high.

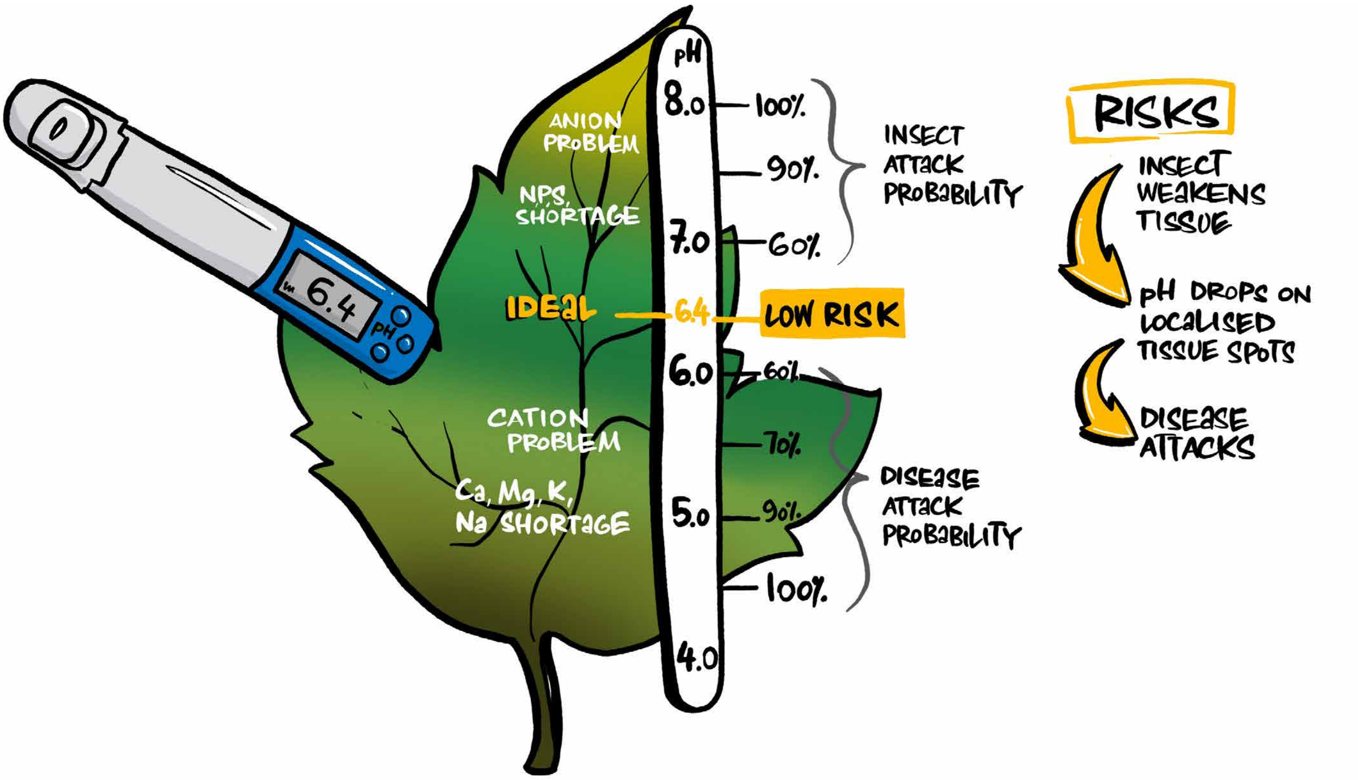

Figure 9. The assessment of plant sap pH can be used to predict the probability of insect and disease risk [modified from Tainio, 2021].

A neutral pH of 7 within the cell fluid means it contains 100 percent saturation of cations other than hydrogen (in other words, the sap contains no free hydrogen ions).

- At a plant's ideal cellular fluid pH of 6.4, the saturation of cations other than hydrogen is about 88 percent. At 88 percent saturation – principally calcium, magnesium, potassium and sodium – the ionization and activity of these elements generates an electrical frequency of between 7.5 and 32 Hertz, which is one of the 'healthy' frequency ranges of all living cells.
- To decrease cellular pH to 6.0 is to lower the saturation of the above four principal elements to 80 percent, thus lowering the plant's frequency to a level of lower resistance to bacterial, fungal and viral plant pathogens.
- Studies have shown that insects are attracted to a plant by the plant's frequency. If the saturation of Ca, Mg, K and Na increases to over 88 percent saturation, the frequency from these ions in the cell are increased, and consequently, insects are attracted to the higher-than-normal cell frequency.
- The same process occurs in animal and human cells. Hydrogen accumulation in the cell tissue means the saturation of Ca, Mg, K and Na is decreasing, thus causing the frequency to decline. This low frequency leaves the cell an easy target for disease.

It is possible to see both insect and disease problems occurring at the same time. This can happen when insects attack due to a high plant tissue pH, and the tissue becomes weakened in the localised areas of attack. Next, localised, rapid energy loss (a drop in pH) occurs at the insect-damaged spots, resulting in tissue disease attack of those areas on the plant.

When a pH shift of a half point (0.5) or more from the ideal 6.4 occurs in the cellular liquid, a laboratory tissue test should be taken to determine exact imbalances, and which materials should be applied.

Tissue pH indicators

- Low pH + moderate Brix = calcium deficiency
- Low pH + low Brix = potassium deficiency
- 6.4 pH + high Brix = balance

Generally, when a plant has a low tissue pH and a moderate Brix level, there is usually a calcium deficiency involved. On the other hand, a low pH with a low Brix level usually indicates a potassium deficiency. The goal is to achieve a pH of 6.4 with a high Brix level.

For a quick adjustment to bring up the pH, calcium can be foliar applied in small amounts (follow label recommendations). To quickly bring down a pH that is too high, on the other hand, small amounts of phosphate can be applied to the foliage.

These types of quick fixes are usually only temporary, however, and should only be used while awaiting a complete tissue test analysis.

The historical information above opens many lines of enquiry. It also highlights the need for future research to test these assumptions for wine grape production and the broader observations that can be gained by taking a new perspective when it comes to grapevine health and resilience against the impact of pathogens.

We encourage wine growers to consider the implications of trophobiosis, plant health and nutritional status when considering their approach to pest and pathogen management (and the drivers for their presence).

Recent research and practical knowledge that ties all these concepts together is presented below in the sections on redox and the plant health pyramid.

REDOX POTENTIAL (Eh)

Along with pH it is important to consider the implications of redox. Redox comes from the words **red**-uction and **ox**-idation = redox.

Reduction is the gain of electrons or a decrease in the oxidation state, while oxidation is the loss of electrons or an increase in the oxidation state.

Soil redox potential (Eh) is used as an indirect measure of soil oxygen status and indicates how oxidised or reduced (anaerobic) a soil is. It is by measured by the difference between oxidation (loss of electrons) and reduction (gain of electrons) (Husson, 2012). There is interest to use redox as an integrative measure of soil and plant condition and an Eh-pH model has been proposed to develop a one health approach (Husson et al., 2021).

Eh is expressed in volts and conditions favourable for plant growth are between 350 to 500 mV with optimum conditions between 400 and 450 mV. It is measured in the field using a specialised electrode.

There are many aspects of this work that are fascinating and have potential applications in production systems. For example, the relationships between Eh, nutrient availability, plant stress and the susceptibility of plants to attack by pathogen and pest species (Husson et al., 2016). This complements the topics covered above.

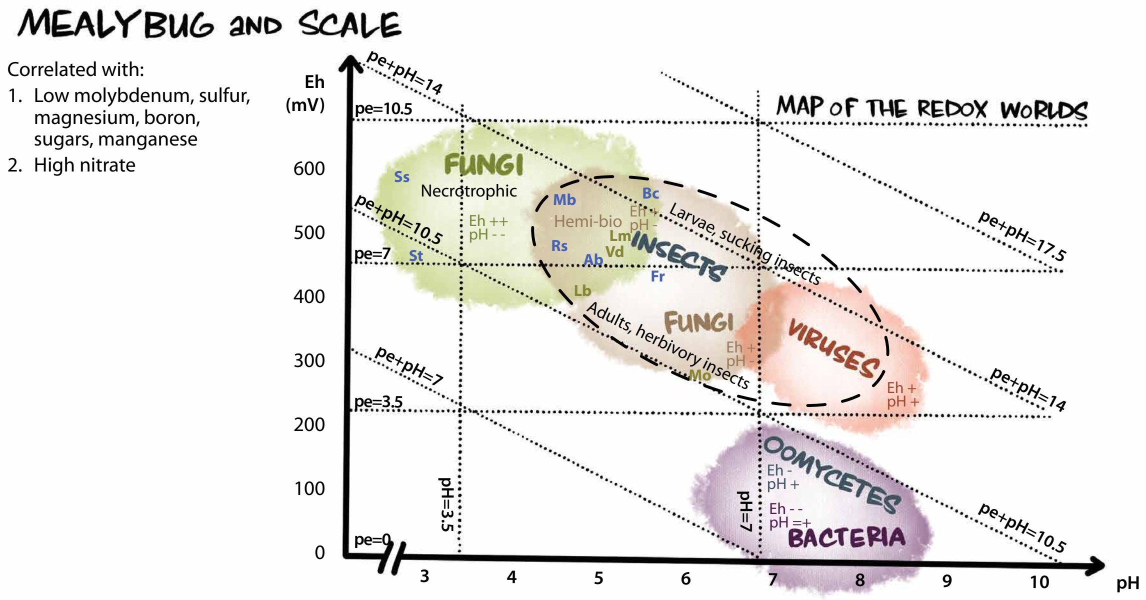

Figure 10. The role of redox potential, nutrient availability and the impact on plant susceptibility to fungi, insects, viruses and bacteria (Husson, 2019; Kempf, 2023).

pH is a measure of the acid-base reaction (transfer of protons) whilst redox measures the oxidation-reduction reactions (transfer of electrons).

Further information

- Investing in regenerative agriculture and food: Olivier Husson, photosynthesis is the biggest lever we have in health, climate, droughts, floods, but most plants are too sick to do it properly
- 2019 Soil and Nutrition Conference: The role of redox potential and reduction-oxidation reactions
- Advancing Eco Agriculture podcast: Redox: the driver of soil microbial interactions with Olivier Husson
- Matt Powers podcast: Episode 127 | John Kempf on soil redox, energy, and nutrient availability

THE PLANT HEALTH PYRAMID

Advancing Eco Agriculture's founder John Kempf is leading the way regarding regenerative production in the USA and he refers to the following five core concepts that are fundamental to the success of regenerative agriculture:

- Healthy plants resist insects and disease
- Mineral nutrition supports plant immunity
- Microbial metabolites are a more efficient source of nutrition
- Quality drives yield
- Healthy plants create health soil

The plant health pyramid developed by John Kempf helps to explain how all the topics mentioned previously fit together and breaks down a plant's journey to complete immunity into four levels.

- Each level corresponds to a distinct physiological process that occurs within the plant
- Each level produces immunity to a new group of pests or diseases
- There are distinct, actionable steps a grower can take to advance their plants to each level.

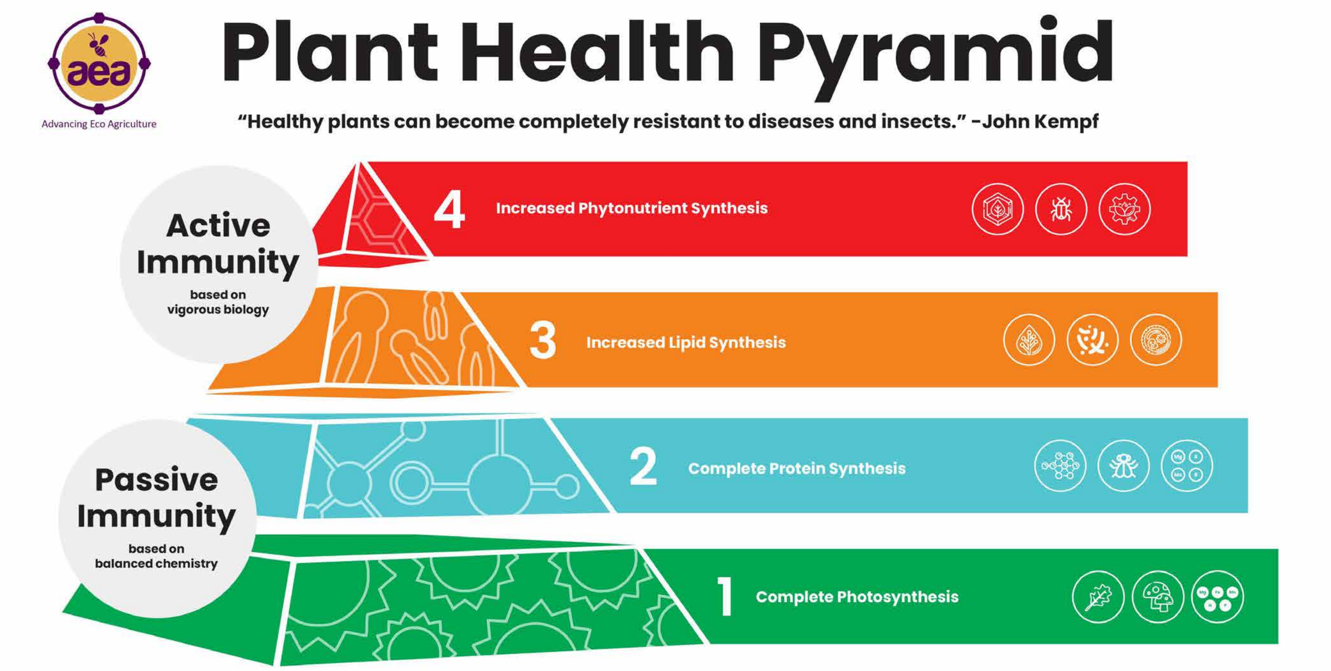

Figure 11. The plant health pyramid (Advancing Eco Agriculture, 2024).

The following summary is paraphrased from Advancing Eco Agriculture (2024):

STEP 1: Complete photosynthesis (this forms the foundation of the following steps)

Plants increase both the quantity of sugars the produce through photosynthesis, by as much as 3-4x, and their quality. The five minerals that are needed for the photosynthetic process are magnesium, iron, manganese, nitrogen, phosphorus.

Plants start to resist soil-borne fungal pathogens

STEP 2: Complete protein synthesis

All the forms of nitrogen the plant absorbs–ammonium, urea, nitrates, or amino acids–are quickly converted into complete proteins. The our minerals that are needed for nitrogen synthesis and pest resistance are magnesium, sulphur, molybdenum and boron.

Plants resist insects with the simplest digestive systems - the larval and sucking insects

STEP 3: Lipid synthesis

In level three, plants produce so much energy that they have a surplus. Just like humans, plants store their surplus energy as fat. Plants at level 3 see at 2-4x increase in lipid synthesis.

To reach this stage of health, plants must absorb the majority of their nutrition from soil microbes.

Plants resist airborne pathogens, including downy mildew and powdery mildew

STEP 4: Elevated levels of plant secondary metabolites

These are compounds that plants create to protect themselves, which have incredibly powerful anti-bacterial and anti-fungal properties.

The right microbes will trigger the plant's immune response, both systemic acquired resistance (SAR) and induced systemic resistance (ISR).

Plants resist pests such as beetles, bugs and nematodes

An in depth analysis of each step is presented on the Advancing Eco Agriculture website, follow this link to find out more about The plant health pyramid.

Further information

For more information how you can improve soil and plant health please refer to:

- Advancing Eco Agriculture: The plant health pyramid
- Advancing Eco Agriculture: Dr Tom Dykstra: How brix levels impact insect pressure on plants
- Advancing Eco Agriculture: John Kempf: Managing crop nutrition (vs. pest management) and sap analysis
- EcoVineyards best practice management guide on soil health in Australian vineyards: Part A (chemical and physical)
- EcoVineyards best practice management guide on soil health in Australian vineyards: Part B (soil biology)
- EcoVineyards best practice management guide on ground covers in Australian vineyards
- EcoVineyards fact sheets in the knowledge hub
- NovaCropControl: Research results on Plant sap analyses in grapes by NovaCropControl
- NovaCropControl: Presentations
- Soil Food Web: Dr Tom Dykstra, Why insects avoid healthy plants
- Soil Food Web: Dr Adrienne Godschalx, How soil food webs shape plant-insect interactions.
- Sustainable winegrowing with the vineyard team podcast: Vine sap analysis to optimise nutrition

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ACKNOWLEDGEMENT OF COUNTRY

EcoVineyards proudly acknowledge the Aboriginal and Torres Strait Islander Peoples, and their ongoing cutural and spiritual connection to this ancient land on which we work and live.

As the Traditional custodians we recognise their wealth of ecological knowledge and the importance of caring for Country.

We pay our respect to elders past and present and extend this respect to all Aboriginal and Torres Strait Islander Peoples.

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