Dirt on PSA and How to deal to it's Multiple Lifestyles

A knowledge base for orchardist to develop their own strategies to combat PSA.

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Introduction

Pseudomonas syringae [a] causes disease in many *species* [b] of plants. It is used as a model organism to understand the genetics [1] and biochemical (*molecular* [c]) basis of plant disease .[2] Pseudomonas syringae causes economic loss in over 180 plant species and therefore has been scientifically studied for over a century. [3]. Many scientific papers have been published about this pathogen, and how plants and beneficial microorganisms interact with it. Substantial scientific knowledge is being accumulated which enables development of effective science based strategies to control the disease Pseudomonas syringae causes.

Pseudomonas syringae pv Actinidiae, (PSA) is a host range variant or strain (*pathovar* [d]) of the species (syringae). PSA is currently known to only infect, colonise and disease Kiwifruit. In all other aspects PSA behaves exactly as other pathogenic Pseudomonas syringae. PSA is now established in New Zealand.

Disease causing (*pathogenic* [f]) Pseudomonas syringae, including PSA, have a multiple life style (*hemibiotrophic* [g]). They can secretly live (symptomless) inside the plant (*endophyte* [h]) feeding on the nutrients plants manufacture (*biotrophic* [i]). Under certain plants' internal and external environmental conditions they can transform and are discharged into the environment on gummosis found in cankers. If the bacteria land on leaves or young shoots they are capable of surviving as *epiphyte* [n], causing no disease symptoms. Under specific conditions they can became aggressive (*virulent* [j]) and multiply, infect, kill and feed on dead plant tissue (*necrotrophic* [k]). [4]

This multiple lifestyle opens up two targets areas (inside and outside the plant) to identify and exploit when developing methods to disrupt their life and control them!

The good news is there are proven, established orchard management practices that scuttle this pathogen and reduce the economic losses in orchards. These horticultural techniques which are cultural methods can be readily applied in PSA diseased orchards.

There are proven, safe, environmentally benign cutting edge biomolecular and biological based technologies that the Kiwifruit industries can use to safely and successfully manage PSA as well as improve productivity.

Another tool worth objective consideration is *Humates* [l] which supports *trophic* [m] (water, soil, plant food web) systems. Humates, like the biomolecular and biological based technologies, also helps to improves productivity.

The fall back position is the availability of many "*new chemistry* [o]" based products on the market that could be tested and developed for safe application in a relatively short time. As these are pesticides their use needs approvals and registrations before they can be tested and used on commercial crop,

Finally there are some orchard practices that need objective consideration as they can be a risk, conducive to disease development. Girdling, soil fertility, use of foliar sprays and compost tea need review.

<u>The solutions- science based strategies</u>

1. Orchard management practices to scuttle the disease.

Disease free / low risk district
Focus on healthy plants and lifting productivity. Treat large pruning cuts and scars.
No infection / high risk district
Focus on healthy plants and lifting productivity. Reduce stress. Treat large pruning cuts and scars. Be vigilant as symptomless infection can progress to the point where overnight a whole cane can wilt and collapse.
Leaf infection found
Remove leaf, treat leaf scar. Spray Serenade/Cu? Focus on vine health. Avoid large pruning cuts and treat old scars. Be vigilant as symptomless infection can progress to the point where overnight a whole cane can wilt and collapse.
Shoot infection found.
Cut 4 cm past dead tissue, burn, treat wound. Inject antibiotics (if approved), Spray orchard with Serenade/Cu. Focus on vine health
Trunk discharges *Remove vine. Bioremediate soil with good composted farm manure. Inject antibiotics (if approved) into surrounding vines. Spray orchard with Serenade*

All orchards apply Copper or Serenade or other biological antagonist before leaf fall.

2. Currently available technologies to strengthen plant's immune and trophic (soil, plant, food web) system and lift productivity.

Plants immune system and trophic system elicitors
Pathogen antagonistic microbes
Humates

THE EMERGING THEME OF THESE BIOLOGICAL BASED SOLUTIONS ARE THEY ARE NOT A COST BLEED ON MANAGING PSA BUT IMPROVE QUALITY AND PRODUCTIVITY TO DELIVER A SUBSTANTIAL INCREASE IN OGR.

3. New chemistry (chemically synthesised pesticide) solutions that may be considered for research & development.

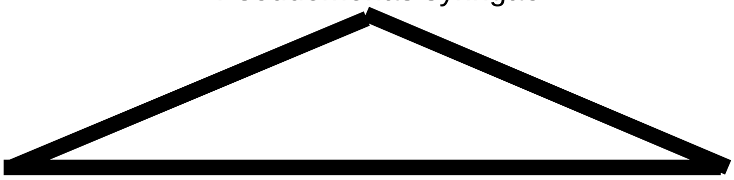
Agrimycine
Kesugamycine
Beta-lactam
Harpin inhibitors - cycloheximide (Streptomyces griseus)
- lanthanum chloride (chemical reagent compound)
- sodium vanadate (chemical protein inhibitor)

Copper

The Science

One of the concepts encountered by the student of plant pathology is this disease triangle.

Bacteria
Pseudomonas syringae



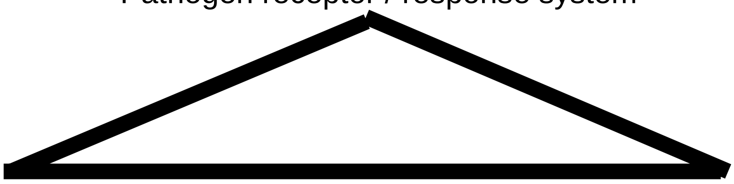
Host
Kiwifruit

Environment
Climate

The simplicity of this model makes it an ideal starting point for exploration of factors promoting disease. This disease triangle relationship conceals the complexity of the myriad interactions involved. [5.] However it allows plant pathologists to chunk the complex interactions down, focus on specific factors and devise methods to disrupt the parasitic association.

Since the Global Human Genome Project we have gained knowledge that has enabled a redraw of the “disease triangle” [5] incorporating new knowledge of internal and external molecular biological interactions as well as the beneficial ecosystem that assists plants to resist diseases.

Bacteria
Pathogen receptor / response system



Host
Repair, growth & defence system

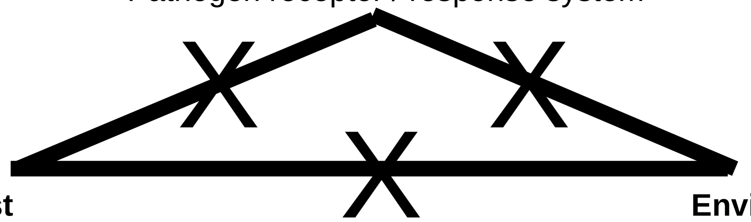
Environment
internal & trophic system + climate

One of the greatest benefits out of the Global Human Genome Project was the discovery of receptor molecules on all organisms. All living organisms (including bacteria) can detect foreign molecules, change in the environment and cell damage and signal to the cellular systems. A response and counter response war at molecular level occurs between the host and invader. [6]

There is now substantial knowledge of how beneficial microorganisms keep pathogens at manageable levels.

There is increasing published knowledge of how plants interact with pest, disease and environment at molecular level.

Plant pathologists have been able to redraw the disease triangle to provide greater opportunities to identify and provide a range of tools to exploit weak or strong disease promoting factors in the relationship and bust the parasitic relationship so that the disease (symptoms) don't manifest.



The huge increase in Molecular biology knowledge is delivering safe and effective management tools to combat pest, disease (*biotic* [p]) and problems such as salinity, drought and other environmental (*abiotic* [q]) stress. To develop these strategies effectively knowledge of the Bacteria, Host and the Internal and trophic system as well as the physical environment that supports disease manifestation is helpful.

Knowledge about Bacteria

Hemibiotrophs like PSA have multiple phases in their life style.

Biotrophic phase.
A symptomless biotrophic stage. The parasite resides in the space between cells (*apoplast* [r]) within the plant (as an endophyte) and robs the plant of nutrients (as a biotroph) it manufactures. The parasite is dependent on its host for food and therefore does not kill the host by causing disease.

Potentially disease causing Pseudomonas syringae are found within "healthy" (symptomless) trees in the wild. [7] It is therefore probable that PSA is in all kiwifruit vines in this symptomless biotrophic form.

The success of P. syringae as a plant endophyte depends on its ability to survive inside plants and multiply in the apoplast of healthy plants. It needs to tolerate defence molecules produced by plants and be able to hijack plant produced nutrients. The internal environmental and nutritional adaptation can take two main forms:

1. The up regulation of beneficial genes that *encode* [s] enzymes and nutrient transporters, which enable consumption of nutrients present in plant environment.
2. and the loss or down regulation of genes that encode enzymes and transporters that are no longer required, or which have a negative impact on growth of the bacteria in the plant environment. [2]

P. syringae produces organic molecules called coronatine as a molecular weapon to disable the plants immune system and support its ability to hijack plant nutrients.

"Transition phase"

The molecular mechanism (*transcriptome* [t] changes [22]) of transition from the biotrophic to necrotrophic phase is being intensely studied.[8] Knowledge of the mechanism will lead to development of technologies that disrupt the transformation of the bacteria to a virulent form and prevent disease manifestation.

Pseudomonas syringae colonisation of leaf stomata without forming symptoms, invasions of leaves and spreading through the veins to stem and trunk have been reported.[3] Symptomless infection of healthy plants can therefore occur. In orchards, the results of the advanced stage of invasion of plant tissue are sudden wilting and death of shoots and canes without visible symptoms on plant surface.

Pseudomonas syringae can grow and survive for several generations as an epiphyte, causing no damage to the plant and growing to high population on leaves. This high epiphytic population on the leaf and not necessarily bacteria originating from necrotic tissue (leaf spots or cane or stem canker) have been proven to be the infecting agents of fresh leaf scars. [3]

Necrotrophic phase

Cell death or necrosis is a wasteful consequence of the disease cycle and usually occurs late in infection when the population of the pathogen has increased to overwhelm the plant and its trophic defence systems.

When Pseudomonas syringae "transforms" to the virulent necrotrophic form it is able to produce toxins. A major toxin is the protein harpin. Harpin tricks the plant to activate its hyper (defence) reaction that causes cell death around the point of "infection". The bacteria consumes nutrients from the dying tissue and the disease progresses as the bacteria continue to produce harpin and elicit the plants own defence system to (progressively) cause cell death and necrosis.

Nonhost environmental reservoirs
Pseudomonas syringae has been isolated from pristine headwaters and some of the variants caused disease in plants. This pristine non host water habitat plays key roles in how the bacteria evolve to become a pathogen. [16]

Survival in soil
Pseudomonas syringae can survive in the rhizosphere of non-host plants four growth cycles in the same soil. It can also survive in the soil associated with buried host plant material. It maintained its pathogenicity increased its population over long period. [26]

Steps in manifestation of bacterial disease (symptoms)
Host recognition, adherence to host tissue, invasion of host tissue (infection), colonization (growth) and parasitisation of tissue, death (necrosis) of tissue (disease manifestation).

Knowledge about Host

Plants live in complex environments in which they intimately interact with a broad range of other organisms. Besides damaging interactions with pathogens and pests, relationships with beneficial microorganisms are frequent in nature as well, improving plant growth or helping the plant to overcome stress. [9]

Plants have immune system.
Plants have a highly sophisticated defense system (immune system). Plants and their invaders recognise foreign molecules and send out signals from both the receptor molecules on the cell membrane and from the injured cells. They respond by activating an effective immune response against each other to defend, repair damaged cells and promote growth. [9] Several cycles of reactions and counter reactions are possible between the plant and the invading pathogens or pest. Most of the time the plant wins and no disease symptoms are seen, occasionally the plant looses and the disease manifests itself.

Plants' immune systems involve a complex network of signalling pathways induced by *plant hormones* [v] such as salicylic acid, jasmonic acid and gaseous ethylene. These hormones (octadeconoids) regulate local and systemic resistance to invasive pathogens.[10]

When plants accumulate salicylic acid, jasmonic acid, and ethylene to certain threshold levels it triggers the Phenylpropanoid pathway which produces the majority of phenolic compounds (essential oils) found in nature. Plants' repair, growth and defence systems (immune system) and their interaction with beneficial microbes and beneficial predators (trophic system) are controlled by these essential oils (phenylpropanoids). [11]

Role of beneficial bacteria inside plants.
Mutualistc endophytes are beneficial microorganisms that protect plants from pests and diseases and can enhance plant growth. [13]

Infection sites
Pseudomonas syringae invades through hydathode, in addition to the stomata and wounded parts. [14]

Knowledge about environment internal & trophic system + climate

Role of beneficial microbes on plants – the plant ecosystem
All plant associated microenvironments (*rhizophere* [w], *phyllosphere* [x], atmosphere) are colonised by a large number of microbes. When microbes were tested in the plant habitat up to 35% showed antagonistic capacity to inhibit the growth of pathogens. [15]
Many potential antagonists have been selected from the fluorescent pseudomonad group, as this group includes various non pathogenic species that are adapted to plant colonisation and well known for their competitiveness. Pseudomonas fluorescens has been proposed as biocontrol organism. [12]

Role of beneficial microbes in the soil – the soil ecosystem
Selected rhizobacteria enhance plant growth and yield with the ability to control pathogens. Although the symbiotic relationship of soil microbes and the plant is usually nutritional, the inter-actions between the soil, host and micro organisms are far more complex, [23]
Objective considerations on how to support this system will deliver increased nutrient use efficiency, reduce the risk of creating salinity problems and bioremediate the heavy metal as well as reduce chemical toxins.

Role of soil nutrients and toxins
In a survey of leaf and soil nutrient, imbalance in nutrients had impact on plant's ability to resist disease. Bacterial disease incidence in pears increased when plants had small unhealthy leaves, had higher levels of aluminium, iron, and potassium. Orchard soils that had excessive levels of copper, and those that were too saline had higher incidence of bacterial disease. [15]

Role of water
Pseudomonas syringae is widely abundant in water including pristine waters outside agricultural regions. There is considerable exchange of populations between freshwater and crops. The freshwater population contribute considerably to the diversification of Pseudomonas syringae. [16]

Weather conditions condusive to disease
Pseudomonas syringae infections are often linked with a cold and wet damage factors in the orchard. Frost, hail damage and excessive overhead orchard irrigation for frost protection have been noted in other crops as environmental factors that favour Pseudomonas syringae bacterial disease.

Pseudomonas syringae produce Ina proteins [24] which cause water to freeze at fairly high temperatures, resulting in injury to plants. The species plays a important role in producing rain and snow. Pseudomonas syringae is therefore able to create the environment that is conducive to its infection and disease manifestation.

Discussion - Scientific evidence and objective observations on recommended solutions.

Pseudomonas syringae causes sporadic disease in the field. Field trials with pesticides (new chemistry products) have not produced valid results against this economically important disease organism.[3] This is due to lack of a suitable experimental design that is robust enough to take into account the sporadic nature of the disease in the field and deliver valid data.

Other scientific process - deduction and elimination process needs to be applied to logically evaluate technology and horticultural or physical (containment) techniques as tools to combat PSA. In 1998 at a USA government funded workshop scientist and farmer delegates were instructed "In the next decade, biologicals will either begin to play a meaningful role in specialty crops or become a curiosity relegated to organic farming. Industry, growers, extension, and researchers must come together and think "outside the mold" to realize the former. "

Knowledge base shifts from Scientist to Farmers!

The workshop recommendations for success was ", biological control products complement natural control. Their use and effectiveness depends on the level of natural control in a particular field, and observations on when augmentation is needed rather than on a calendar-based, *prophylactic* [z] basis. Thus, **farmers are key elements of successful integrated pest management (IPM) and engaged in regular observation, decision making, and the conservation of natural enemies**. Consequently, biological products in a new paradigm are knowledge-intensive and require that farmers understand their crop ecosystems and the dynamics of their arthropod inhabitants, both good and bad. Under various circumstances, this local IPM **expertise might be held by the farmers themselves as a result of farmer field school training**,"

1. Orchard management practices to scuttle the disease.

These recommendations are based on proven horticultural practices carried out on various crops.

Disease free / low risk district

Focus on healthy plants and lifting productivity. Treat large pruning cuts and scars.

This recommendation to use productivity as a yardstick is based on grower observations on plant health in relation to productivity.

Quoting an orchardist who has for the past 4 seasons used agrizest® "You can't get that sort of production unless they are healthy," he says. "Once you've got healthy plants all the other things start to happen for you." Peter Hope , Orchardist, Katikati. Phone 0274272329.

Surveys of bacterial diseases breakout in orchards has established that the sporadic patterns of the disease in orchards or districts are due to the differences in the health of plants. Healthy plants were infected but did not develop disease symptoms. [15]

No infection / high risk district
Focus on healthy plants and lifting productivity and reduce stress. Treat large pruning cuts and scars. Be vigilant as symptomless infection can progress to the point where overnight a whole cane can wilt and collapse.
Up to 4 day incubation period could happen before any symptoms are noticed! Sometime symptomless disease progression can lead to sudden wilting and death of shoots and canes weeks after the weather event. Note in the photo how even the neighbouring cane look healthy!

In spring Consider using ThermoMax when cold wet conditions, frost or hail is forecasted or use agrizest® *after frost or hail damage has occurred.*

***DO NOT USE* agrizest® POST HARVEST AS IT WILL UPSET THE PLANTS GROWTH CYCLE.**

Leaf infection found
Remove leaf & burn, treat leaf scar. Spray Serenade/Cu? Focus on vine health. Avoid large pruning cuts and treat old scars. Be vigilant as symptomless infection can progress to the point where overnight a whole cane can wilt and collapse.

Shoot infection found.
Cut 4 cm past dead tissue, burn, treat wound. Inject antibiotics if approved, Spray orchard with Serenade/Cu. Focus on vine health
Cut past wilting and dead tissue. Peel back bark until clear that there are no threads of necrotic tissues. Sterilise secautares and cut 4cm back into healthy tissue.

Trunk discharges *Remove vine and a root ball. Bioremediate soil with good composted farm manure. Inject antibiotics (if allowed) to surrounding vines. Spray orchard with Serenade*

All orchards apply Copper or Serenade or other biological sprays **before leaf fall**. High epiphytic population of Pseudomonas syringae on the leaf have been proven to be the infecting agents of fresh leaf scars. [3]

Do not use **agrizest®** post harvest as it will upset the plants natural growth and rest cycle.

Winter & spring objectively consider the use of ThemoMax, agrizest®, Humates. Review fertilizer levels and interaction aspects specific to the orchard.

2. Currently available technologies to strengthen plant's immune and trophic (soil, plant, food web) system and lift productivity.

Plants immune system and trophic system elicitors
Pathogen antagonistic microbes
Humates

Alternative methods based on prevention, biological control and plant (immune) resistance are the current science focus. **THE EMERGING THEME OF THESE BIOLOGICAL BASED SOLUTIONS ARE - THEY ARE NOT A COST BLEED ON MANAGING PSA BUT THEY IMPROVE QUALITY AND PRODUCTIVITY TO DELIVER A SUBSTANTIAL INCREASE IN OGR.**

The biologicals, elicitors, antagonistic microbes, and humates operate at multiple levels delivering a range of benefits.

Consider the elicitor, agrizest®. agrizest® is an invention that tricks the plant to “think” it is being attacked by pest, disease and environmental changes. The plant reacts by producing essential oils (phenylpropanoids).

Because. agrizest® works through a (genetically controlled) system rather than on a single target it delivers a range of benefits in your environment, and your orchard. This range of benefits adds up to a substantial increase in orchard gate returns.

The cascades of polyphenols (essential oils) that agrizest® activates the plant to produce and accumulate have been proven in numerous laboratory tests to reduce Pseudomonas syringae isolated from various diseased crops.[19]

agrizest® efficacy against Pseudomonas syringae or any other beneficial effect cannot be tested in the laboratories (invitro tests) because it does not have direct effect like pesticides or fertilizer. agrizest® works indirectly by eliciting and sustaining the plants own production of essential oils (phenylpropanoids) which controls the plants immune system functions.

All the claims that agrizest® will improve health, quality and productivity (OGR) are backed by independent commercial split block trial data.
(browse http://www.agrizest.com/Kiwifruit_Page.html)

In an agrizest® trial block on Gold Kiwifruit orchard, situated in the middle of the “PSA priority zone” one PSA infected leaf was found in early February. The disease did not manifest or the infection spread to other neighboring foliage. Agrizest treatment appears to have strengthened the plants immune system or fighting fitness to ward off the disease.

Post PSA infection incidence the orchardist sprayed (4 applications) of agrizest® on the rest of orchard. The disease has not spread outside the block where the disease was 1st found.

Another Gold Kiwifruit orchardist in the “PSA priority zone” on Te Matai Road reported leaf spotting in agrizest® treated block (comparatively less than in control block) but the disease did not manifest, neighboring leaves remained healthy.

NOTE: NO DEFINATIVE RESULTS CAN BE OBTAINED FROM FIELD TRIALS BECAUSE THE OF THE SPORADIC NATURE OF THE DISEASE.

Antagonistic microbes also deliver a range of benefits, again through engaging the plants immune system which results in accumulation of cascade of essential oils. The mechanisms of immune response include

1. developmental escape: linked to growth promotion,
2. physiological tolerance: reduced symptom expression, preserving quality,
3. environmental: associated with microbial antagonisms in the rhizophere, and
4. biochemical resistance: induction of cell wall reinforcement, induction of phytoalexins, induction of pathogenesis related proteins, and “priming” of defense responses (resistance).[17]

The range of benefits biological products deliver, including the actions against disease can improved orchard gate returns.

Humates too have multi function in the rhizosphere and delivers improved health and productivity in crops.

1. The carboxyl and phenol groups are able to form chelate complexes with microelements and transform them into plant available form.
2. They also improve the ion-exchange capacity of soils. Other groups, which are called quinones, are able to capture and accumulate solar energy.
3. The humates form insoluble compounds with heavy metals, which creates the barrier for their penetration into the cell and leaching into waterways.
4. Soil rich in humates have higher ecological balance.
5. Another important quality of the humates is their ability to bond aluminium ions into complexes and prevent aluminium induced phosphorus deficiency in plants.
6. Iron forms complexes with the humates, and aids translocation into plants. Humates bioremediate soil pesticide (including herbicides) contamination.
7. The colloidal structure of the humic acid and its hydrophilic properties increases soil water retention.[18]

Humates impact on encouraging beneficial microbes, reduction of stress from herbicides, drought, salinity (high fertilizer applications), bioremediation effect on copper and aluminium needs objective consideration. The range of benefits can lift OGR while reducing the risk of PSA disease problem.

3. New chemistry (chemical pesticide) solutions to research and develop.

Agrimycine
Kesugamycine
Beta-lactam
Harpin inhibitors - cycloheximide (Streptomyces griseus)
- lanthanum chloride (chemical reagent compound)
- sodium vanadate (chemical protein inhibitor)

Copper

The pesticides products are difficult to develop because they are used in medicine, spraying in orchards are banned to mitigate development of cross resistance. However, it is worth considering injecting antibiotics, agrimycin or kesugamycin at early infection stage. The technique avoids environmental contamination and reduces the dosage substantially. [21] This practice may save having to destroy the whole plant and loosing orchard productivity.

Agrimycin or Kesugamycin are antibiotic compound. The seasons fruit may have to be destroyed. Based on trials with Kesugamycin on kiwifruit there was no detectable level of residue in Kiwifruit. The trials were done decades ago and the techniques these days could pick up residues at much lower levels. Care in use of antibiotics in agriculture is required because in the EU "compost tea" or naturally fermented nutrient sprays are being re-examined for antibiotic compounds that may have similarities to antibiotics used in medicine. Use of antibiotics in agriculture (except for animal treatment) is banned in the EU to avoid bacteria developing resistance to them.

Beta-lactam is a group of antibiotics which includes penicillin derivatives.

Pseudomonas syringae produces a protein called harpin which is an elicitor that tricks the plant to think it is being attacked by an organism that usually feeds on fresh tissue. The plant reacts, causes “programmed” cell death around the “infection” area in order to starve the perceived “fresh tissue feeding parasite”. The perverse Pseudomonas syringae then feeds on the nutrients found within the dying cells. Both natural and chemical inhibitors of harpin are commercially available.

Harpin inhibitors
- cycloheximide (Streptomyces griseus)
- lanthanum chloride (chemical reagent compound)
- sodium vanadate (chemical protein inhibitor)

These inhibitors have already been developed for medical use.
Chances are not too bright for development of these products for use in orchards but it is worth a try using new techniques such as the injection technique used for bud rot trial.[21]

Copper is phototoxic when applied in spring.[21] copper will affect floral bud development in spring and reduce your crop. Italian scientist report 20% to 30% reduction in crop load.

Copper is a general anti microbial agent.
Copper application will reduce the beneficial microbes present in the orchard.
Copper application is phytotoxic , may reduce your crop load.

4. Orchard management practices that needs review

Girdling,

Trunk Girdle

Cane Girdle

Leaf stress (4 days after cane girdle)

Some orchardist experience decline in vine productivity and have observed stress symptoms.

Japanese scientist claim girdling reduces incidence of PSA.

Girdling is used in New Zealand to increase fruit quality and productivity.

Orchardist need to objectively review this cultural practice in relation to PSA management.

To mitigate risk (as an alternative) could consider use of agrizest® programme- proven to increase OGR without girdling.

Soil fertility,
There are 3 columns in the bar graph of your soil fertility test [25] – interpret it correctly. Medium is desired range (note there is no absolute value). Within this range good production is expected. High is the toxic level! Low is the deficiency level. Only add sufficient nutrient to maintain the level within the medium range. The ideal level within the medium range will depend on the interactive level with other nutrient elements and the ion exchange capacity of the soil. It is a complex and important area which needs careful calculations and justifications.

Leaf and soil nutrient imbalance were found to promote bacterial disease. Diseased trees had small unhealthy leaves. The leaves had higher levels of aluminium, iron, and potassium than healthy fully expanded leaves. Orchard soils had excessive levels of copper, and were too saline.[15]

Fertilizer applications that exceed the soils exchange capacity will lead to soil salinity. Apply correct levels of nutrients to the soil; top up level should not exceed the recommended medium level.

The soil biological systems deliver about 80% of the nutrient uptake. The current chemical soil test method does not account for the biologically derived nutrient levels. Improve the balance and microbial health of soil. Objectively consider use of humates.

Foliar nutrients that include phosphate & potassium,
Foliar nutrients that contain Phosphate and Potassium can reduce fungal disease. [20] Recent molecular biology studies however discourages the use of **foliar** application of Phosphate and Potassium because they upset the nutritional balance that keeps endophytic pathogens like Pseudomonas syringae in check.[2] The elicitation of plants' immune system with basic elicitors like phosphate and potassium can predispose plants to necrotrophic Pseudomonas syringae. The part of the immune system Pseudomonas syringae hijack to kill and feed on is primed by foliar application of potassium or phosphate thus predisposing the plant to disease manifestation. Only use foliar nutrients to correct deficiencies.

The upset of nutritional balance with the plant has been implied as probable effectors for Pseudomonas syringae changing its life phase from endophyte to epiphyte.

Do not upset the interaction of nutrients in soil or within plants. Refer to Appendix 1 for further information of soil fertilizer interaction.

Compost tea
Application of "compost tea" is known to reduce disease and promote productivity.

Fermented foliar feed material can be contaminated with beta lactam, the molecule from which antibiotics like streptomycin are produced. Residue aspect needs attention when using "compost tea" or other organic fermented foliar sprays.

Strategies Development Template

Based on the information given in this document, orchardist can develop strategies that take into account their management needs and knowledge of their orchard.

Use the template on (next page) this document to develop your strategy

Action	Benefits	Implementation Fit	Risks	Cost Management Research	Milestone Indicators

This action plan template can be used for listing of the actions, evaluating the gathering evidence.

ACTION REQUIRED	RESPONSIBILITY	COSTS	TARGET DATE	INDICATORS	STRATEGIC FIT	MILESTONE APPROVAL
How do we do it?	Who is going to do it	Material, application , residue testing, evaluation cost +? +? =	By what date?	How will we know when it's done?	How does this relate to our goals	How did we get on

Give it a go – under each column heading you will find a guiding note to help it along.
If you need help phone Nathan Balasingham on 09 2383893.
Or contact via email – nathan@indigo-ltd.co.nz.

Glossary

a. *Pseudomonas syringae* - is a rod shaped, Gram-negative bacterium with polar flagella. It is a plant pathogen which can infect a wide range of plant species, and exists as over 50 different pathovars. P. syringae also produce Ina proteins which cause water to freeze at fairly high temperatures, resulting in injury to plants. The species plays a larger role than previously thought in producing rain and snow. These Ina proteins are also used in making artificial snow. (Reference: Wikipedia)

b. *species* - A species is often defined as a group of organisms capable of interbreeding and producing fertile offspring. Species that are believed to have the same ancestors are grouped together, and this group is called a genus.

c. *molecular* basis – based on biological system chemistry or biochemistry.

d. *pathovar* - is a bacterial strain or set of strains with the same or similar characteristics, that is differentiated from other bacteria of the same species based on their ability to cause disease on one or more plant hosts. All other characteristics and behavior of the pathovor is the same for the whole species.

f. *pathogenic* – organisms that disease or capable of causing disease.

g. *hemibiotrophic* - a microorganism that parasites living tissues, hijacking some of the nutrients of the host for a period (symptomless disease) and is also capable of transforming into form that is able to invade fresh tissue, killing it and surviving by deriving its nutrients from the dying or dead tissue of the host.

h. *endophyte* - a bacterium or fungus, that lives within a plant for at least part of its life without causing apparent disease some are beneficial microorganisms that contribute symbiotically in the growth and defence process of the host.

i. *biotrophic* – pathogenic and beneficial microbes establish a long-term feeding relationship with the living cells of their hosts, rather than killing the host cells as part of the infection process. These pathogens and beneficial microorganisms are termed biotrophic [from the Greek: bios = life, trophy = feeding]. Typically, these microorganisms grow between the host cells and sometimes invade only a few of the cells. The parasitic endophytes feeding activity creates a nutrient sink. The host is disadvantaged but is not killed. This type of parasitism can result in serious economic losses of crop plants, and in natural environments it can reduce the competitive productivity abilities of the host without apparent disease symptoms. This type of parasitism is very sophisticated - keeping the host alive as a long-term source of food.

j. *virulent* - measure of the severity of the disease caused by pathogens.

k. *necrotrophic* – parasites that derives its nutrition by feeding on host cells by killing host cells or on dead host tissues. Their action produces dramatic disease symptoms.

l. *humates* – a water soluble solids produced when humic acid is reacted with an alkaline agent

m. *trophic* – the hierarchical nutrient or food dependent relationship

n. *epiphyte* – a organism that lives on plants and derives support and non parasitic nutritional benefit. There is no mutual benefit as in symbiosis.

o. *new chemistry* – chemically systhesised fertilizer and pesticides.

p. *biotic* – relating to, produced by, or caused by living organisms

q. *abiotic* – environment related effect.

r. *apoplast* – the space between cells that are rich in plant produced nutrients

s. *encode –* reading the gene sequence and producing biomolecular building block or blocks coded in the gene sequence.

t. *transcriptome* - The genome is made up of deoxyribonucleic acid (DNA), a long, winding molecule that contains the instructions needed to build and maintain cells. For these instructions to be carried out, DNA must be transcribed into corresponding molecules of ribonucleic acid (RNA), referred to as transcripts. A transcriptome is a collection of all the transcripts present in a given cell. (Reference – National Genome Research Institute www.genome.gov)

u. *pathogenicity* - Pathogenicity is the ability of a pathogen to produce an infectious disease in an organism. It is often used interchangeably with the term "virulence" (Reference wikipedia.org)

v. *plant hormones*- are plant produced biochemicals that regulate plant growth and function.

w. *rhizophere* - is the narrow region of soil that is directly influenced by root secretions and associated soil microorganisms (Reference wikipedia.org)

x. *phyllosphere* - is a term used in microbiology to refer to leaf surfaces or total above-ground surfaces of a plant as a habitat for microorganisms (Reference wikipedia.org)

y. *ecology* - is the scientific study of the relation of living organisms with each other and their surroundings (Reference wikipedia.org)

z. *prophylactic* - is a treatment designed and used to prevent a disease from occurring

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Appendix 1

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http://www.apal.com.au/site/DefaultSite/filesystem/documents/APAL%20PLANT%20NUTRIENT%20INTERACTIONS%20July%2008.pdf

PLANT NUTRIENT INTERACTIONS

Antagonism

Mulder's Chart shows some of the interactions between plant nutrients.

High levels of a particular nutrient in the soil can interfere with the availability and uptake by the plant of other nutrients. Those nutrients which interfere with one another are said to be antagonistic.

For example, high nitrogen levels can reduce the availability of boron, potash and copper; high phosphate levels can influence the uptake of iron, calcium potash, copper and zinc; high potash levels can reduce the availability of magnesium. Thus, unless care is taken to ensure an adequate **balanced supply of all the nutrients** – by the use of analysis – the application of ever higher levels of nitrogen, phosphorus and potassium in compound fertilisers can induce plant deficiencies of other essential nutrients.

Stimulation

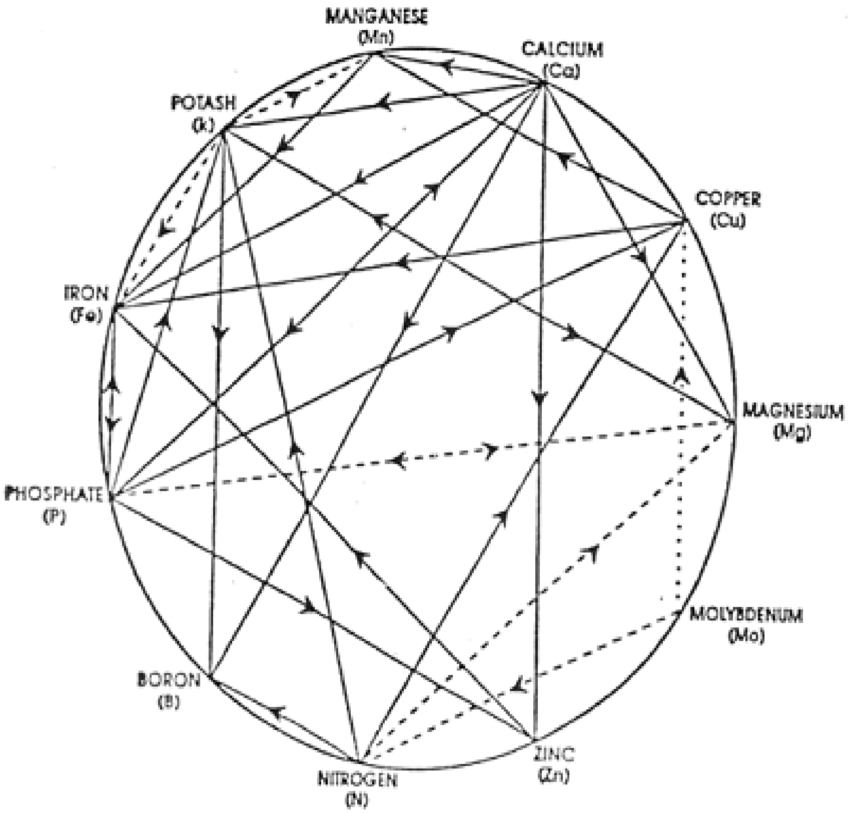
Stimulation occurs when the high level of a particular nutrient increases the demand by the plant for another nutrient.

Increased nitrogen levels create a demand for more magnesium. If more potassium is used – more manganese is required and so on.

Although the cause of stimulation is different from that of antagonism, the result is the same – induced deficiencies of the crop if not supplied with a balanced diet.

High levels of molybdenum in the soil and in the herbage reduce an animal's ability to absorb copper into the blood stream, and ruminant animals grazing these areas have to be fed or injected with copper to supplement their diet (see Mo/Cu dotted line).

Mulder's Chart



ANTAGONISM ——▶ A decrease in availability to the plant of a nutrient by the action of another nutrient (see direction of arrow).

STIMULATION .... An increase in the need for a nutrient by the plant because of the increase in the level of another nutrient.