RESOURCE GUIDE

Organic Citrus

WRITTEN BY Allan Morton & Dieter Proebst
PROJECT MANAGER Gavin Kenny ILLUSTRATED BY Fred Robertson

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This Guide is the result of the contributions of many people made during the answering of a questionnaire, reviewing of the first draft, attending one of three workshops held in Kerikeri, Katikati and Gisborne, and participating in the final review and editing process: your input is much appreciated. Special thanks are also due to David Skinner, Keith Pyle, Viv Milne, Hamish Payne, Jamie and Mary Graham, who have reviewed organised and participated in the process, and Gavin Kenny under whose guidance this project was completed.

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Organic Citrus Resource Guide

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Soil&Health Association of New Zealand Inc.

Earthwise Consulting

The Bio Dynamic Farming and Gardening Assoc. in N.Z. Inc.
Founded on the work of Rudolf Steiner

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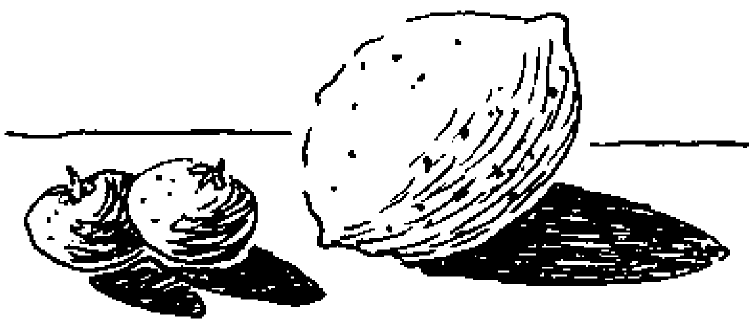


Preface

In the first half of 2001 a successful application to the Sustainable Farming Fund was made on behalf of the Bio Dynamic and Soil and Health Associations. The project aim was to draw on the knowledge and experience of established organic and biodynamic producers and make it more widely available. The first step was to identify key sectors where we felt the project would make a difference and involve experienced organic people associated with those sectors who were keen to contribute. As a result we focused the project on: dairy/pastoral farming; and avocado, citrus and summerfruit production. Successful organic producers are pioneers, as they acknowledge that there are always more questions than answers and thus are continually taking on new challenges. That capacity to take on new challenges has been very evident in this project. Individuals have taken on multiple challenges; they have acted as workshop facilitators, field day organisers and presenters and have written and collated material for a series of Resource Guides. Many others have contributed through their participation at workshops and field days, by acting as reviewers and giving their time to make written contributions. This Resource Guide is a result of that work.

It is important to be clear as to what this Resource Guide isn't and what it is. It isn't a detailed technical 'how to' document, as there is no simple prescribed pathway towards successful organic production and there are still many more questions than answers. It is a number of things. First and foremost it is a multi-authored collation of existing knowledge, presented from a practical perspective. Second, there has been a deliberate weaving together of organic and biodynamic information. The purpose of weaving together a range of views is to provide you with choice – take what is relevant to you at any given time and ignore what you don't consider to be relevant. Third, it is intended to be a 'living resource'. We've drawn together what is known to help you avoid making the mistakes that others have and achieve success more quickly and also to allow for clearer identification of gaps in knowledge so that these can be addressed. In summary, this document won't make you a good organic producer, it is not a technical 'how to' manual, it is intended to be a practical, living Resource Guide. It is meant to guide, not to prescribe.

Gavin Kenny, Earthwise Consulting Ltd
Project Manager
August 2003

Avocado, Citrus, Pastoral and Summerfruit Resource Guides are available from the Project Manager (telephone 06 870 8466 or email gavinkenny@clear.net.nz) or in Adobe Acrobat (.pdf) format from www.organicnz.org and www.biodynamic.org.nz.

Introduction

> *'The tree is graceful having elongated leaves and dense foliage, covering the ground with dark shade. In flowering time it is particularly full of poetical purity and elegant remoteness. The fruits are all quite spherical, the texture of the skin being shiny as wax. On a morning after early frost when the gardener picks the fruit and presents it (to his master) its beauty impresses everyone. When it is opened, a fragrant mist enchants people.'* – *Han Yen-Chih of Yenan 1178AD*

The natural goodness and abundance of nature is certainly wonderfully expressed in the fruit of citrus. Of all fruits, citrus are perhaps most closely associated with good health and high vitamin content. These qualities are most fully captured when cultural methods work with nature, rather than in opposition to it. The orchard is also part of the surrounding landscape whose overall health depends on that of its individual parts. Organic growing aims to answer these two needs – to preserve as much as possible the natural goodness of the fruit, and to make the orchard a valuable contributing component of the wider ecosystem and landscape.

Organic is both a well-defined approach to agriculture(1,2) and a marketing term indicating that the item has been produced organically. Organic farming systems refrain from the use of synthetic and concentrated chemical fertilisers, synthetic pesticides and herbicides and synthetic chemical food additives. They seek to minimise external inputs to the farm by conserving and recycling nutrients and to preserve and enhance the functioning of the orchard ecosystem so that it is self-regulating. This means that pests and diseases are kept in check by the natural processes of nature and the need for direct intervention by the grower is minimised. This approach means that the impact of farming operations on the environment is reduced and the long-term productivity of the land is preserved for future generations.

Organic agriculture is part of and often leads a general trend towards greater sustainability in agriculture. The theme of constant improvement is a noted feature of this drive towards increased sustainability. This has been described by Stuart Hill(3) as consisting of a three stage succession. First comes the stage of 'efficiency', when there is a reduction of inputs by better timing and placement. This is followed by the stage of 'substitution', when more benign inputs are substituted for broad-spectrum insecticides and other 'hard' inputs. Finally comes the stage of 'redesign', when causes rather than symptoms are treated. In this stage the farm is redesigned to foster natural ecological balances, thereby avoiding many problems altogether. Redesign represents the frontier of the move towards sustainable land use and the production of quality food. It is the present-day challenge offered to organic growers and if successfully met will ensure that organic agriculture retains its leadership position at the frontier of modern agriculture.

Citrus is generally considered a marginal crop in the relatively cool New Zealand climate. Most commercial citrus growing occurs in Gisborne, Bay of Plenty and from Auckland northwards, although citrus orchards are also found in many other parts of New Zealand, including northern parts of the South Island. Most citrus varieties are reasonably well suited to organic cultivation and the main pests and diseases cause only superficial skin blemishes. Nevertheless, the production of high quality fruit requires careful and skilled management. This Resource Guide has been compiled from the combined experience of established organic citrus growers to assist those wanting to produce good crops of high quality citrus fruit using organic growing methods. It is intended to be a living document to be altered, updated and improved as the know-how is discovered and shared. As a Resource Guide it will hopefully contain information of use to experienced growers as well as to those more recently involved with organic citrus culture. There are two important ingredients to being a successful organic grower:

The pathway to success

There are two important ingredients to being a successful organic grower:

1) **Access to information – this Resource Guide provides you with a start**
2) **Support from others. You can achieve this by:**
    - **Joining an organic discussion and support group can be a big help. This enables you to have support, especially through the transition period. Once you have some experience, this will in turn help support others in the group**
    - **If there is no discussion group in your area, try and get one going, even if it is only two or three people, and**
    - **If this is not possible, find yourself a mentor who you can phone and visit when you need to.**

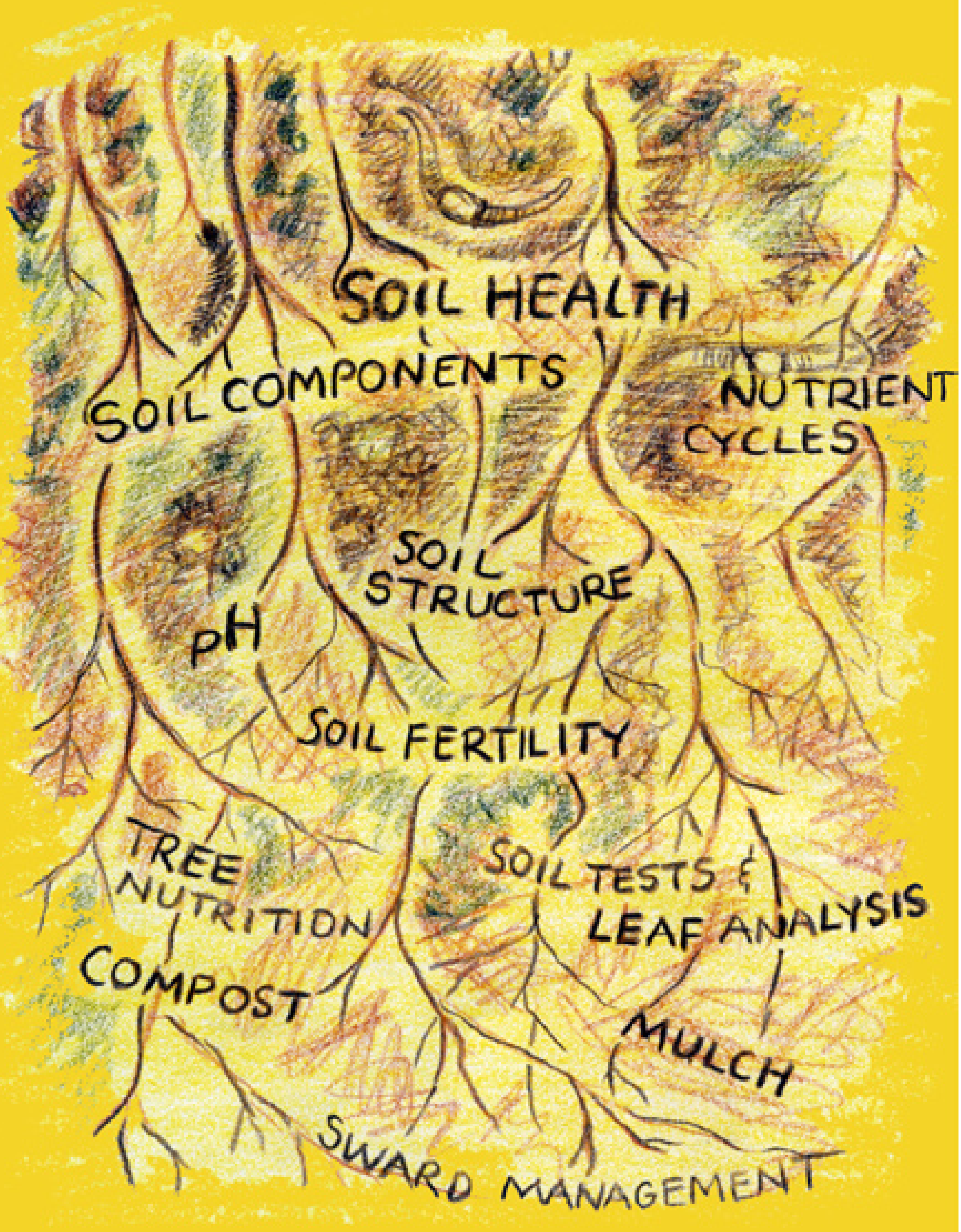
As part of this project there is an associated email discussion group for sharing information and experiences. To join the group send an email to Peter Urich (pbu@waikato.ac.nz) expressing interest in the group and you will be subscribed.

1. Le Guillou, G. & Scharpe, A. (2000). Organic farming: guide to community rules. Luxembourg: European Communities. Retrieved 9 April, 2003 from World Wide Web: home.prolink.de/~hps/organic/abio_en.pdf

2. Gold, M.V. (1999). Sustainable agriculture: definitions and terms. Special Reference Briefs Series no. SRB 99 – 02 . USDA. Retrieved 9 April 2003 from the World Wide Web: www.nalusda.gov/afsic/AFSIC_pubs/srb9902.htm#term1

3. MacRae, R.J., Hill, S.B., Mehuys, G.R. & Henning, J. (1990). Farm-scale agronomic and economic conversion from conventional to sustainable agriculture. *Advances in Agronomy*, 43: 155-198.

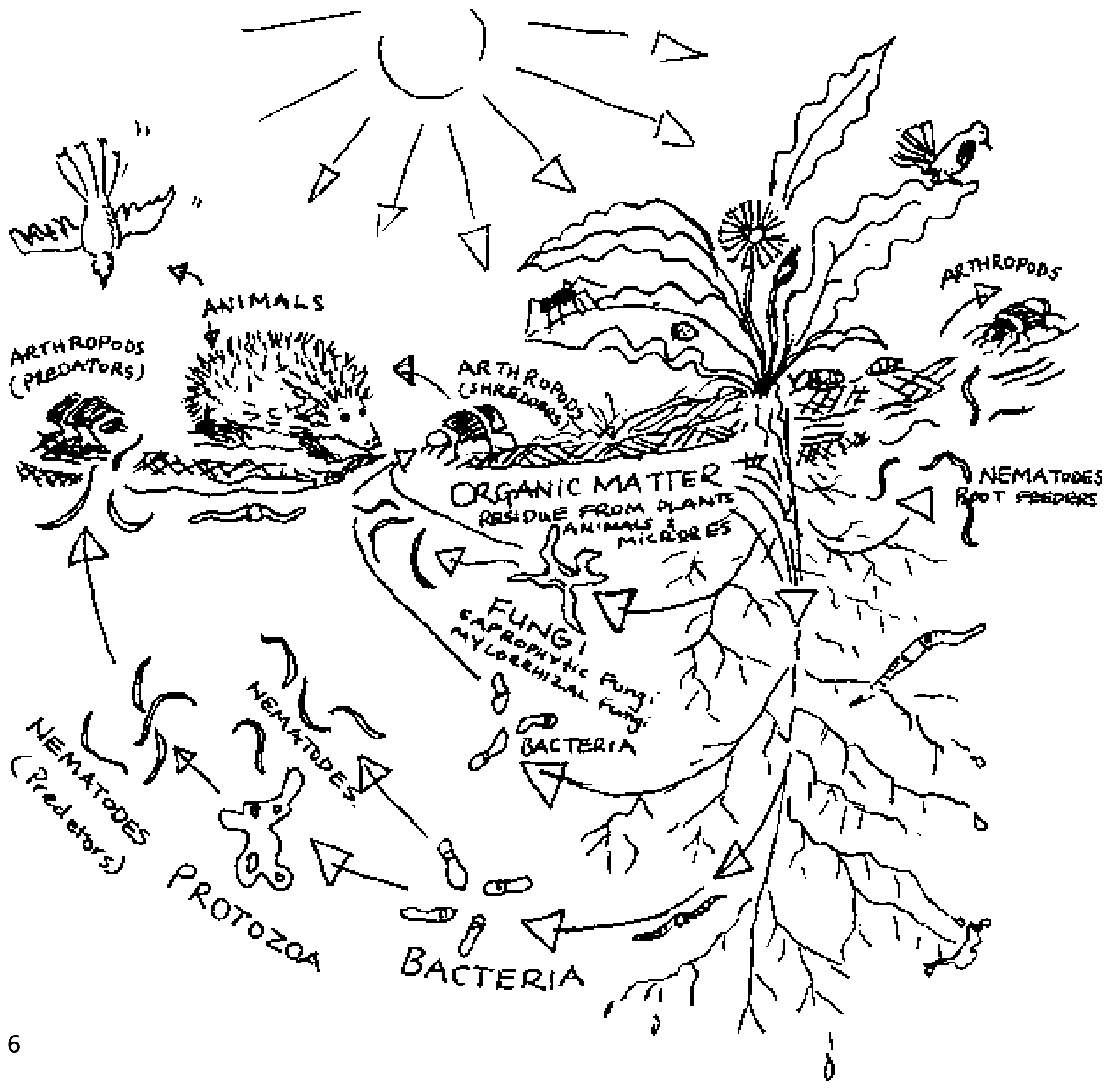
Soil, sward and tree



Soil sward and tree are the main structural components of the orchard – interconnected and interdependent. Much of what happens in the orchard at all levels depends on the interactions and flow of energy and mass between these three.

Soil management

The orchard and its annual offering of fruit is a product of its soil. A biologically active, well-structured and fertile soil is a healthy soil able to produce and to sustain healthy productive plants. The most important activity on an organic orchard is the creation and maintenance of healthy soil which is the basis of successful organic growing. The soil is full of life, including plant roots, animals, bacteria, fungi and other microorganisms. The aim of organic horticulture is to manage the soil so that this living system thrives continuously, is fertile, and gives optimum conditions for growing healthy plants. It is these soil organisms that are responsible for the recycling of nutrients and maintenance of soil structure, both of which are essential for the growth of plants. The soil organisms, in turn, depend on the photosynthetic activity of the plants, which produces the raw material and energy for their existence. The flow of energy and mass between all the soil organisms has been described as a soil food web.



Soil components

The basis of terrestrial life, the soil is a dynamic matrix of minerals, plant roots, microorganisms, soil animals, humus, water and air.

Minerals

The mineral fraction of the soil represents the parent material from which the soil is derived (e.g. basalt, granite or greywacke) and that is being weathered to release its elemental components (typical to the rock type), many of which are important for plant growth. Mineral particles include very small clay particles, medium sized silt particles and large sand particles. Of course, some soils also contain stones and rocks. The distribution and proportion of clay, silt and sand largely determine the soil's texture and account for the different soil types. Soil texture is an important factor in determining air, water and nutrient holding capacity. Sandy or coarse textured soils are usually free draining and well aerated, but have a low water and nutrient holding capacity. Clay or fine textured soils are more likely to have impeded drainage and limited aeration, but have a high water and nutrient holding capacity. Silty soils are somewhere between these two extremes.

Organic matter

Soil organic matter (SOM) includes living organisms as well as their residues and dead remains. While soil organic matter forms only a relatively small proportion of the total soil bulk, its functions are the basis of soil fertility and productivity, especially in organic systems. Increasing SOM levels is an important part of managing soil organically. Between 4 and 10% would be considered ideal.

Plant roots are by far the largest component of SOM in terms of total biomass (average about 20t/ha). Roots exude and shed carbon compounds into the soil that are an important food source for microorganisms, particularly bacteria. In fact, the soil's microbial activity is concentrated around plant roots in a zone known as the rhizosphere ('rhizo' meaning root).

Plant roots and above ground parts are constantly being recycled and this is the main source of food and energy for the soil food web. It is the energy fixed by photosynthesis into carbon compounds that supports virtually all life forms. Plant roots and above ground parts are constantly being recycled and this is the main source of food and energy for the soil food web. Plants are basically made of carbon compounds created through the process of photosynthesis that occurs in their leaves in sunlight. These compounds are both food and energy source for virtually all other life forms.

Microorganisms largely control the rate that nutrients are recycled and become available for plant uptake. They are the basis of the soil's life. A diverse range of organisms is needed to successively break down the wide range of compounds contained in organic matter and to release nutrients from soil minerals. Plant diversity and organic matter inputs are important factors, increasing the diversity of soil microbial populations. Organic practices such as the use of compost, cover crops, crop rotations, intercropping and mulching will all contribute to soil microbial diversity and proliferation. As nutrients are mineralised and enter the soil solution they are rapidly absorbed by plant roots or other organisms.

If nutrients and moisture are available, soil pH is close to neutral and soil temperatures are within 10–30° C, then soil microbes will flourish; if the food substrate is diverse, then populations will also tend to be diverse. If soil conditions are not ideal, most soil microbes and many of the soil animals can enter a dormant stage in the form of cysts or spores enabling them to survive periods when conditions are not suited for growth. However, as soon as conditions become suitable growth can be very rapid.

Fungi are next to plant roots in terms of total biomass (typically: 2-5 t/ha). They are active in the decomposition of mainly dead organic matter, although some species are also pathogenic. Other species (mycorrhizae) form symbiotic relationships with plant roots, providing the plant with nutrients and water in return for a supply of carbohydrate. Mycorrhizae also protect plant roots from attack by pathogenic organisms.

Bacteria are the most numerous soil organisms and are active in the decomposition of organic matter. Individual bacteria are much smaller than fungi and their total biomass is typically 1–2t/ha. Organic matter consists of many different compounds and the breakdown of especially the larger compounds requires specific microbe species for each stage of the decomposition. Both the processes of decomposition and the formation of humus require a large and diverse bacterial population in the soil. Some bacteria are able to fix atmospheric nitrogen. Of these species, the most important are those that form symbiotic relationships with legumes (rhizobia).

Actinomycetes have characteristics of both fungi and bacteria. They are active decomposers and some species are pathogenic. They contribute much of the earthly smell of soil. Total biomass: 0–2t/ha. Algae are another bacteria-like group of organisms that live mainly near the surface where there is light. They are photosynthetic and some species can also fix nitrogen.

Microfauna are microscopic animals that perform important functions in the soil such as regulating, by predation and grazing, populations and biomass of bacteria and fungi. The main members of this group are protozoa and nematodes. Involved in a similar way are the slightly larger **mesofauna** which includes small soil animals such as springtails and mites. All these soil animals exist in amazing variety and numbers in the soil and feed on a wide range of foods including bacteria, fungi, dead organic matter, plant roots and each other. As a result of their combined activity the release of nutrients and plant growth is regulated.

Earthworms are the most important of the larger soil animals (macrofauna). Others include molluscs, ants and centipedes. The larger soil animals break organic matter down into smaller pieces and incorporate (and inoculate) it into the soil for microorganisms to decompose. They also graze on microbes, other soil animals and plant roots, releasing nutrients and spreading inoculant. Earthworms and other macrofauna are also important in creating space in the soil (soil structure) for other soil organisms.

Humus is partially decomposed organic matter that is resistant to further decay as a result of the microbial and chemical processes of humification. Humus forms aggregates with soil mineral particles, often being enclosed in a mineral coating and therefore protected from further microbial decay. It has a high nutritional content and represents the soil's long-term nutrient supply. The more stable humus can have a turnover rate of tens or even hundreds of years.

Water and air are essential for nearly all life forms including those found in soil. Soil water holds dissolved nutrients for plant uptake, and many soil organisms need a water film to swim around in. Organic matter, especially humus, adds to the soil's water holding capacity. Air is needed for aerobic (air-breathing) organisms, including plant roots. Aeration or gas exchange is also necessary to allow the removal of metabolic wastes – gases such as carbon dioxide and methane produced by soil organisms (including plant roots).

Mycorrhizae are fungi that form symbiotic relationships with the roots of most plants, receiving carbohydrates from the plant and in return supply the plant with a wide range of nutrients (including phosphorus and nitrogen). Furthermore, mycorrhizal associations protect the plant from root pathogens and may produce hormones (e.g. cytokinnins) that stimulate the growth of the host plant[4]. The network of fine fungal threads greatly extends the plant's root-system and increases the soil volume able to be utilised in the search for nutrients. The most benefit is likely to be gained in situations of relatively low fertility. Excessive applications of phosphate fertilisers can reduce mycorrhizal activity, as can many other conventional agricultural practices (e.g., chemical fertilisers, pesticides, tree girdling). Inoculation with preferred species of mycorrhizal fungi is possible. Organic soil management practices including sward and crop diversity will encourage mycorrhizal fungi.

Earthworms are one of the most important soil organisms. Their abundant presence in soil can be used as an indication of high levels of soil biological activity and health. For example, in a one spade-square hole (i.e. 20x20cm) at least 15 to 20 worms should be found. Earthworms improve both the physical and the chemical fertility of soil. Their tunnelling improves drainage and incorporates surface organic matter into the soil. Soil and organic matter that has passed through the gut of a worm (casts) is microbially and nutritionally enriched. Earthworm activity can be encouraged in the orchard by minimising soil tillage, applications of organic matter to the soil, increasing soil calcium levels by liming, avoiding dry and exposed soil and minimising copper fungicide use.

Rhizobia are the bacteria that form symbiotic relationships with legumes and are able to fix atmospheric nitrogen (N) and supply this to the plant, receiving in return a supply of carbohydrates. They are most active in neutral to slightly alkaline soil with adequate soil moisture levels. They are less active in a soil already rich in N from fertiliser or other nitrogeneous inputs, because the legume will prefer to obtain its N directly from the soil, without having to pay the rhizobia for it with carbohydrates. Additionally, in a N-rich soil grasses will become more competitive and will tend to replace legumes such as clover. In the orchard the N contained in legumes becomes available to other plants when the sward is mown and the clippings decompose or naturally, as the legume roots and foliage die off and decompose. The greatest amount, however, may be deposited directly into the soil from the roots[5].

The rhizobia form visible nodules on the roots of legumes and their nitrogen fixing activity can be confirmed if these nodules have a pinkish colour inside. On clover plants if the nodules are clustered near the soil surface this could indicate unfavourable soil conditions.

Soil structure

Soil structure is the formation of soil particles into aggregates, their arrangement relative to each other and the stability or resistance to stress of the resulting 'structure'. It is within the structure of the soil that water and air are held. A strongly structured soil is able to retain a crumbly texture even after repeated cultivations and has the strength to resist compaction. A weak structured soil, if cultivated or disturbed, will soon collapse into fine sand or silt particles and is easily compacted. A soil with good structure will be porous and light, roots will penetrate it easily, its water and air holding capacity will be high and it will drain quickly. Humus, with its role in aggregate formation, is important in the formation of soil structure, as is the activity of plant roots, soil microbes and earthworms. Microbes produce glues and coatings that bind soil particles and organic matter together forming aggregates. Earthworms burrow and mix and have a significant rotary hoeing effect. Other factors involved in the creation of soil structure include wetting and drying cycles, clay particles and metal oxides that have a cementing action.

The gaps between soil particles and aggregates are the soil's pores. Soil pore space and soil structure in some ways refer to the same thing. Together with channels made by worms and plant roots, the soil's pores allow the soil to breathe, i.e., they allow gas exchange. The larger soil pores also allow water to enter the soil and to drain away, while the smaller pores hold water for roots, microorganisms and other soil creatures to use until the next rain (or irrigation).

If there is too much water in the soil, so that even the larger pores are water filled and there is little air or gas exchange, then soil is likely to become 'anaerobic'. Where there are anaerobic conditions, the soil's biological activity changes, with many organisms becoming inactive or dying, while others switch to an anaerobic metabolism, creating waste products that are toxic to plants and soil organisms (e.g., methane, alcohol, hydrogen sulphide). Plants vary in their tolerance of anaerobic or water-saturated soils. During spring and summer, when plant roots and soil organisms are most active, there is a greater demand for oxygen and gas exchange. At these times plants and other soil organisms will be less tolerant of excessive soil water. Citrus trees have a low tolerance of anaerobic or wet soil conditions, which leads to die back, reduced growth, pale or yellow foliage or tree death.

It can now be seen that the soil's biological activity and structure are very much interdependent. The development of a strong and extensive citrus rootsystem is also promoted by good soil structure. Therefore the maintenance and improvement of structure is a major part of soil management. Soil structure in the orchard can be damaged by compaction by machines or animal treading, especially during wet weather or when the moisture content is high. Vehicles should be excluded from the orchard as much as possible and traffic confined to designated routes. It might also be useful to consider the type of machinery being used – small lightweight machines with air-filled balloon tyres would cause less compaction. Another way structure is harmed is by the repeated use of herbicides that interrupt the recycling of organic matter. Bare ground is also liable to structural damage by exposure to rain, wind and sun. Structure is improved by inputs of organic matter and by having an active and diverse sward, both of which will encourage earthworms, microbial activity and aggregate formation, leading in turn to the development of soil structure.

Soil pH

Soils can be either acidic or alkaline to varying degrees and the measure of this is called the pH of the soil. A soil is neutral at pH 7 (neither acidic or alkaline). A slightly acidic soil (pH 5.8–6.5) is suitable for most agricultural plants. A soil pH of between 6.0 and 6.5 is optimal for citrus. While most citrus growing soils in New Zealand will tend to be acidic, those around Gisborne are often alkaline.

Soil tends to become acidic in time due to interactions with plant roots and microorganisms and by the removal of nutrients in crops or by leaching. Some fertilisers and soil amendments can also have an acidifying effect on the soil. The rate of acidification will be largely determined by the soil's buffering capacity and by rainfall (i.e., leaching).

Many nutrients, including trace elements, become unavailable to plants when the soil is excessively acidic or alkaline. The common citrus rootstock trifoliata can perform poorly above pH 6.5 because of impaired uptake of magnesium, iron, manganese and zinc.

Several other soil/plant factors are also affected by a low soil pH:

- Aluminium and manganese become more soluble and can become toxic to plants
- The activity of soil organisms is inhibited, including earthworms and nitrogen fixing bacteria (including those in symbiosis with legumes)
- Soil cation exchange capacity (CEC) is reduced. Soil CEC is an important indicator of the soil's capacity to store (exchange) nutrients (cations)
- Soil surface structure affecting water infiltration, water retention and aeration which are often reduced.

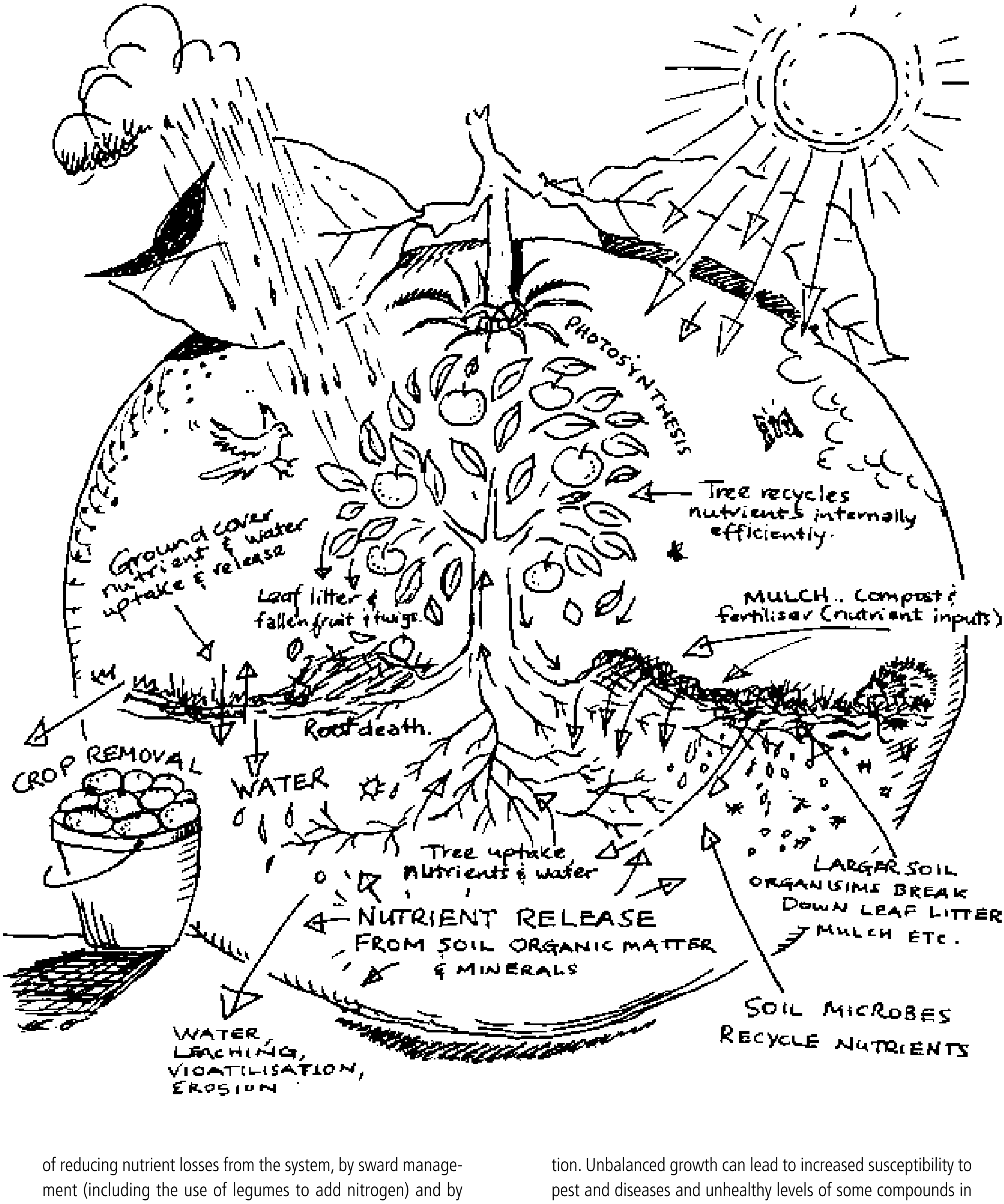
Elemental sulphur or iron sulphate could be used to lower soil pH but this would seldom be practical because of the large quantities that would be needed. Soil pH is usually raised by adding lime or dolomite. Dolomite contains magnesium carbonate as well as calcium carbonate, but if magnesium is not required, lime is the cheaper option. However, the liming effect of many other materials is often overlooked. For example, compost, seaweed, crushed shells, wood ashes and rock phosphate can all raise soil pH significantly. Rock phosphate, for instance, could have about 50% of the liming effect of calcium carbonate – the main component of ordinary agricultural limestone. If the soil is already alkaline, then there is an additional reason to take account of the liming effect of organic soil amendments.

The amount of lime needed to raise soil pH varies according to soil type. Typical applications range from between 1.25t/ha to 2.5t/ha depending on soil type, initial and target pH. To avoid excessive pH changes in a narrow soil layer, large applications of lime should be avoided. Small but frequent applications, that include allowance for other pH altering inputs and combined with periodic pH monitoring, is better. Before planting a new orchard, larger lime applications to neutralise an acid soil might be used (e.g. up to 4t/ha); the lime could be cultivated into the soil. Organic systems that include pH-raising inputs such as compost and rock phosphate might not need regular liming. Lime should be applied separately from nitrogenous inputs such as compost to avoid the loss of N in the form of ammonia that can result from high pH.

Nutrient cycles

The orchard's nutrient pool is contained in the leaves, wood and roots of the fruit trees, in the leaves, stems and roots of the sward plants, dissolved in the soil solution, stored more or less permanently in or on soil minerals and humus, incorporated into the bodies of soil organisms and contained in the residues of animals and plants. Nutrients are moving between these forms as plants and plant parts grow and die, minerals are weathered and formed, humus is broken down and formed, and soil organisms live and die. For example, the extensive fibrous root system of citrus trees dies and is replaced approximately every 2 years and leaves can be replaced at a similar rate. The sun drives the whole system via photosynthesis and the fixing of atmospheric carbon by plants.

Inputs to the orchard nutrient pool come from the weathering of soil minerals, from biological fixation (nitrogen) and from applied soil amendments and fertilisers. Small amounts can also come from atmospheric deposits (sulphur, nitrogen, potassium, sodium). In natural ecosystems very few nutrients are lost from the system. Nutrients are cycled from plants to soil and back into plants. The orchard system, however, loses nutrients through the removal of harvested products (Table 1), as well as by increased rates of leaching and erosion. Ideally nutrients should be returned to the orchard soil from where the fruit is consumed. In the future this may become a reality[6], but at present, nutrient management in the organic orchard consists



of reducing nutrient losses from the system, by sward management (including the use of legumes to add nitrogen) and by adding nutrients from outside sources.

In the organic system crop nutrition is based on the slow microbe-mediated release of nutrients from soil organic matter (SOM). Nutrients are added mainly in an organic form, such as compost. The conventional approach to crop nutrition is based on the use of highly soluble chemical fertilisers that release large amounts of nutrients simultaneously into the soil solution. This can lead to unbalanced growth and environmental pollution. Unbalanced growth can lead to increased susceptibility to pest and diseases and unhealthy levels of some compounds in the produce (e.g., high nitrate levels). Conventional fertilisers can also cause the depletion of other nutrients and SOM and interfere with the processes of humification[7].

In the organic orchard the emphasis is placed on feeding the soil and its microbial population, rather than directly feeding the crop.

Soil fertility

Soil fertility is the capacity of the soil to support the growth and productivity of the crop. The two main components of fertility are soil structure and the quantity of nutrients that are available for plant uptake. The availability of the nutrients to the crop, and for that matter to the rest of the soil community, largely depends on soil structure. Thus the maintenance of fertility is as much about building and preserving soil structure as it is about adding nutrients.

Most horticultural systems are operated at relatively high levels of fertility compared to other farming systems and, particularly, to natural ecosystems. The organic ideal of independence from external nutrient inputs (developed with less intensive pastoral and arable farming in mind) does not apply so well to organic horticulture. The level of production expected by most organic citrus growers can only happen in highly fertile soils and will usually require significant nutrient inputs to be maintained. Soils vary greatly in fertility and therefore in the amount and range of nutrient inputs that will be needed for satisfactory production. Some soils are naturally fertile (e.g., alluvial river flats and some volcanic loams), while others have had their fertility raised by a history of legume-based pastures and intensive fertiliser programmes. High yields may not be sustained if this initial fertility is depleted by inadequate nutrient inputs. Local knowledge of a particular soil and its best management is often a valuable resource that can be drawn on.

High fertility increases the risk of nutrient loss by leaching and erosion. These losses can then cause pollution elsewhere in the environment. Such losses are less likely to occur from organic orchards because of more efficient nutrient cycling, better soil structure, less bare ground and a more vigorous sward. However, they could still occur if excessive quantities of an organic soil amendment were applied, especially before heavy or prolonged rain. Therefore, it is important to limit nutrient inputs to quantities able to be utilised by the trees and sward, and to reduce the risk of runoff by maintaining vegetative buffer zones around the orchard, especially adjacent to waterways.

Repeated applications of the same type of organic soil amendment can result in soil nutrient imbalances. For example, annual applications of composted chicken manure can result in excessive soil phosphate levels. Soil nutrient levels should therefore be monitored by regular soil tests and the nutrient composition of amendments should be known either by analysis or by reference to published information sources[8]. The nutrient value of many organic soil amendments is variable, both between different batches and over time as they mature or age. Therefore, estimation of application rates should be guided by nutrient analysis of bulk inputs. Using nutrient-rich soil amendments can also change the nutrient composition of the fruit. Such changes may not be favourable and this is another reason for not overdoing the amounts that are applied.

Fertilisation of the orchards has two stages; building fertility and maintaining fertility. Where necessary fertility must be built up over a period of years with relatively large nutrient inputs. Once soils have been improved to a satisfactory extent as indicated by soil tests, foliar analysis and tree productivity and appearance, inputs can be reduced to maintenance levels. Nutrient inputs should then be estimated on the basis of nutrients removed in crops, while allowing for other factors such as winter leaching loss and tree growth[9,10]. Young trees that are making rapid growth need relatively higher nutrient inputs than mature trees.

Table 1. **A range of nutrients lost from the orchard in a 25 tonne crop of oranges.**
Source: Spiegel-Roy & Goldschmidt[11].

Element	Kg/ha	Element	Kg/ha
Nitrogen	30	Phosphorus	6.5
Potassium	62.5	Magnesium	5
Calcium	25		

Table 2. **Approximate nutrient content in some common organic soil amendments (kg/tonne).**

Material	Nitrogen	Phosphorus	Potassium
Compost (municipal green waste)	8.25 (6.6)*	1.38 (1.1)	5.50 (4.4)
Compost (fish/bark)	12.3	1.4	3.3
Meat & Bone meal	60.0	70.0	
Chicken manure	9.0	10.0	9.0
Fishmeal	80.0	40.0	-

* Numbers in brackets = kg/m3; Note: American and European sources measure phosphate and potassium content of fertilisers according to the oxide content (P2O5 & K2O), whereas in NZ the elemental content is measured (P & K). To convert %P2O5 to %P divide by 2.3; to convert % K2O to %K divide by 1.2

The management of soil fertility depends on maintaining a biologically active soil, which can release nutrients from the soil making them available for crop growth. If this can be achieved, then dependence on purchased fertilisers, mineral or organic, can be reduced without necessarily any significant yield reductions. A nutrient deficiency problem should be solved by assessing and amending the physical and biological condition of the soil, the balance of rotations and suitability of horticultural practices. Building a healthy fertile soil is a long-term process and is unlikely to be achieved in one or two seasons.

Before soil amendments are used on certified orchards, careful reference should be made to the standards of the relevant certifying body (e.g., Bio-Gro, Demeter or AgriQuality).

Tree nutrition

The main soil derived nutrients needed by citrus and other plants are divided into two main groups according to the amounts required. All must be adequately supplied to the plant for satisfactory growth, productivity and health. The first group, the macro-elements, are required in relatively large amounts, while the second group, the micro or trace elements, are required in only small amounts. The macro-elements include nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulphur (S). The trace elements include iron (Fe), manganese (Mn), zinc (Zn), copper Cu), boron (B) and molybdenum (Mo). Citrus have a particular demand for N, K, Mg and Zn. Numerous interactions occur between these plant nutrients that can enhance or inhibit their uptake.

The productivity of the trees is more determined by the long term management of tree nutrition in contrast to 'quick fix' attempts to fertilise the crop directly. Feed the soil not the crop.

For information on permitted fertiliser and nutrient sources for certified organic orchards refer to the certification standards of the certifying bodies (see Organic Certification in the Making it Work chapter).

Nitrogen

Citrus have a high nitrogen (N) requirement and N is often deficient in organic citrus trees. This nutrient is highly mobile in the soil so that soil reserves are constantly changing. Heavy rain and prolonged wet periods can cause much of the plant available N in the soil to be washed (leached) deeper into the soil (or into the ground water) and beyond the reach of plant roots. Leached N from agricultural land is a major source of environmental pollution. During flowering and the spring growth flush, when the plant's need for N is greatest, soil N levels are naturally low as a result of winter leaching and cold soil conditions. Deficiency symptoms are reduced flowering and fruit set and yellowed leaves. Excessive N can result in small fruit, thicker peels, poor colour, delayed maturity, higher acidity, lower Brix:acid ratio and increased susceptibility to pests and diseases. High levels of N in the plant are also associated with low levels of many other elements. Adequate supplies of N promote vegetative growth, flowering and fruit set.

The main reserves of N in the orchard are held in SOM and in the above and below ground parts of sward plants and citrus trees. For example, SOM can hold between 850 and 9000kgN/ha/15cm topsoil in a peat and volcanic soil respectively. Much of this N reserve is in a constant state of flux as soil organisms consume plant debris, humus and each other. Thus, factors that affect the activity and quantity of soil organisms will directly affect N availability. For example, both dry and cold soil conditions will reduce N availability. N held in SOM is made available for plant uptake slowly over time, reducing the risk of leaching loss. Because all living organisms require N for growth, there is strong competition for it in soils. Particularly competitive are grasses and other sward plants; significant proportions of the soil N pool can be 'tied up' in an unmown sward. Plants take up N as either mineralised nitrate ($NO3^-$) or ammonium ($NH4^+$) or as larger organic compounds, such as amino acids or proteins.

Citrus trees store N in roots and wood, and much of the N used by the tree during flowering and fruit set is translocated from these stores rather than taken up from the soil directly. Low soil temperatures inhibit root uptake of N during winter and spring. This indicates the value of raising levels of stored N by applying N-rich soil amendments during summer and autumn. The mineralisation of N from citrus leaf and tree residues has been recorded at between 58–84kg/ha/yr for 4-year-old trees and 126–153kg/ha/yr for 20 year-old trees(12).

The most concentrated sources of N for the organic orchard are the high protein animal products such as meat and bone meal, dried blood and fishmeal (Table 2). Alternative less concentrated but generally preferred sources of N include animal manure, compost and green vegetable matter (e.g., grass clippings and green manure crops). Soil amendments being used to supply N are usually applied in early spring, although uptake might be increased with autumn applications. There is greater risk of leaching from autumn applications, so care should be taken to apply no more than can be taken up by the trees or orchard sward. For this reason autumn applications should be made earlier rather than later. Most of the nitrogen in compost is likely to be mineralised (become plant available) during the three months following application – so compost applied in May will be releasing nitrogen during some of the wettest and coldest months of the year (June, July) when plant uptake will be reduced and leaching at a maximum. Spreading the compost or manure evenly will reduce leaching loss with the interlaced root systems of sward and trees more likely to intercept and utilise mobile nutrients. Liquid manures applied sparingly, evenly and often, are an efficient way of supplying N.

N is usually applied in conventional citrus orchards at rates of up to 200kgN/ha/yr. In an organic orchard it would be reasonable to use meat and bone meal or fishmeal at between 1 and 2kg/tree/year for mature or average sized trees in moderate to low fertility soils. Assuming a five by three metre tree spacing, this would equate to 40–80kgN/ha/yr. In a certified organic orchard production standards will require these materials to be hot composted before use. The N content of compost varies widely depending on composting method, age and feedstock (Table 2). To supply 50kgN/ha from a compost containing 8.25kgN/tn (6.6kg/m3) would require about 6 tonnes (8m3) of compost. There may be a limit for nitrogen applications imposed by certifier (e.g., 170kgN/ha/yr for Bio-Gro).

Apart from the input of nitrogenous materials, N can be supplied by legumes such as white clover included in the orchard sward and Tasmanian blackwood and alders included in the shelterbelts or hedgerows. The amount of N fixed by white clover can vary widely depending on soil fertility, proportion of clover in the sward and climatic conditions. How much becomes available to the trees also varies according to its distribution on the orchard floor in relation to the tree's roots and how the sward is managed. Between 118 and 126 kgN/ha/2yrs was reported fixed by white clover in an organic apple orchard[13]. As SOM increases under organic management, the amount of internally cycled N also increases and so the need to apply extra N declines. Management then controls its availability to the trees by mowing and mulching, and conserving it against leaching loss by storing it securely in a long sward during winter.

Phosphorus

While citrus have only a moderate demand for phosphorus (P) compared to many other crops, this element is often in short supply in New Zealand soils. As a result of the increased biological activity in the soils of organic orchards, better utilisation and availability of P can be expected. For example, fungal associations with plant roots (mycorrhizae) help to supply the plant with P, especially when the soil supply is low. A low soil level of P does not necessarily mean plants are not obtaining sufficient amounts; and leaf analysis can show this. Deficiency symptoms can include premature loss of leaves, reduced flowering, stunted growth and thick-skinned fruit. Adequate P promotes flowering, fruitset, fruit quality and canopy development.

Soft rock phosphates (reactive rock phosphate or RPR) are suitable for supplying P in organic orchards. The plant availability of RPR may be increased if it is first composted. While not as soluble as superphosphate, over a period of several years it is equally effective as a source of P. Perhaps in the alkaline soils and relatively low rainfall of the Gisborne area there would be more benefit from composting or microbial activation of RPR before application. RPR also supplies calcium. Deposits of low cadmium RPR suitable for organic farming systems are of limited extent globally and so the use of RPR as a P source is not sustainable. Phosphate mining is also associated with environmental pollution.

Because citrus fruit contains little P, the amount removed in crop is relatively small. Apart from RPR, many organic nutrient sources are good sources of P (e.g., meat and bone meal, fish meal, animal manures, wool wastes and wood ashes). Plant based composts may have lower P content than those based on animal wastes.

Many soils, particularly those of volcanic origin, have the property of chemically binding P into non-plant available forms ('P retention' in soil tests). While the increased inputs of organic materials and resulting increase in microbial activity should help in ensuring P is available to plants, more attention would need to paid to P availability on these soils. Conventional soil tests for P measure only the mineral P and not the organic P, of which large amounts may be present in SOM. Young trees with small, undeveloped root systems and lacking mycorrhizal associations are more likely to need additional P.

Potassium

Potassium (K) is needed in relatively large amounts by citrus. Citrus fruit contain large amounts of this nutrient and so losses with harvested crop are correspondingly high. K is considered important in plant health, hardiness and resistance to disease. Lemons need more K than other citrus. Deficiencies include excessive preharvest drop and leaf fall, small fruit and reduced vegetative growth. An excess can cause thin peels, high fruit acidity, low juice content and reduced Brix:acid ratio. Adequate supplies promote return bloom and fruit size and quality. Depletion of K following a heavy crop may be a factor in biennial bearing.

Soils vary widely in the amount of K they contain. Many soils contain minerals with high K content. Weathering processes are constantly releasing K from these minerals to the soil. Highly weathered and leached soils such as the volcanic soils of Kerikeri are likely to have low K reserves, while the young alluvial soils of Gisborne have high K reserves. Conventional soil tests only show plant available K but don't give any indication of the soil's long-term reserves. Past use of K fertilisers may have raised the level of K in some soils.

K is relatively mobile within the soil and so is liable to be leached. It also competes with other nutrients for positions on exchange sites (where nutrients are stored on the surfaces of soil particles) displacing them, which can lead to their loss by leaching. Similarly, K competes with other nutrients for plant uptake, most notably with magnesium. Consequently, magnesium deficiency can result if excessive K is applied. Plants can take up excessive and toxic amounts of K if it is available (termed – luxury uptake). Repeated applications of organic soil amendments that are high in K and particularly of the highly soluble mineral forms such as potassium sulphate, potassium chloride and Patenkali, could result in excessive levels of K in the soil.

Many organic soil amendments contain plenty of K. For example, large amounts of K can be supplied in mulches of straw, hay and seaweed. Other sources include wood ashes, compost, comfrey and urine. Feldspars and other rock dusts often contain K, although usually in small amounts, so their value as fertilisers, when their cost is accounted for, is small. Patenkali, which contains K and Mg, would be the preferred potassium fertiliser if a mineral form were used. Potassium chloride should not be used because citrus are intolerant of chloride. Some people view the use of soluble K fertilisers in organic certification systems as being contrary to basic organic soil management principals.

Magnesium (Mg)

Citrus are sensitive to Mg deficiencies. A deficiency can be due to low soil reserves, high levels of soil K competing for uptake or translocation from leaves to fruit with heavy crops. Deficiency causes blotchy interveinal yellowing of leaves with an inverted green 'V' at the base of the leaf. It can make manganese and zinc deficiencies worse. Trees lacking Mg can have smaller, less coloured fruit and can be more subject to biennial bearing.

Many organic soil amendments will contain significant amounts of Mg. If extra Mg is needed it can be supplied with mineral fertilisers such as dolomite (a magnesium–calcium carbonate mineral), Patentkali (a potassium–magnesium sulphate mineral), Epsom salts (magnesium sulphate) or kieserite (a magnesium sulphate mineral).

Calcium (Ca), sulphur (S), sodium (Na)

These nutrients will usually be adequately supplied by most soils and are present in most organic soil amendments. Calcium is commonly applied as lime or gypsum. Additional sulphur could be supplied as elemental sulphur or as sulphate with other mineral fertilisers (e.g., gypsum).

Trace elements

Trace elements, although needed in only 'trace' or very small amounts, are nevertheless essential for plant development. Some soils may be inherently deficient in one or more trace elements, or plants may not be able to extract them due to some nutrient imbalance or microbial factor. For example, high levels of NPK can lead to reduced zinc and copper uptake by inhibiting mycorrhizal activity[14]. Identifying the soil type, being aware of local knowledge concerning it and particularly, leaf analysis, can help discover trace element deficiencies.

Trace elements will usually be well supplied with organic soil amendments, so that trace element deficiencies may be less likely to develop in organic orchards. Fish and seaweed products are especially good sources of trace elements. Different plant species are able to accumulate higher amounts of some trace elements ('dynamic accumulators') (Table 3), sometimes, in the case of deep rooting plants such as chicory and comfrey, obtaining them from deeper soil levels and bringing them to the surface where they can become part of the orchard's nutrient pool.

Rock dusts can also be a source of trace elements. Common rock based products, including rock phosphate, lime, dolomite and various potassium minerals, usually contain many other elements in varying amounts. However, they can also contain toxic elements such as cadmium and arsenic or trace elements in excessive and toxic amounts. To be effective rock dusts need to be finely ground. The bioavailability of the nutrients contained in rock dusts could be improved by composting.

Animal manures and particularly municipal bio-solids (sewage sludge) and fish-based products (especially deep-sea derived), can also contain toxic trace elements such as cadmium, mercury and lead. The technology to remove heavy metals from municipal wastes is at least theoretically possible and in the future this huge resource will be doubtless be utilised, making far more sustainable agricultural systems possible[6].

Zinc

Zinc (Zn) is a relatively common deficiency in citrus[15]. Deficiency symptoms are similar to those for Mg deficiency but the interveinal chlorosis is less blotchy and more defined. High levels of P, Ca and a high pH can inhibit uptake of Zn. Zn is often present in unavailable forms in soils. Increasing soil biological activity is likely to make these reserves more available. Zn is likely to be supplied with many organic soil amendments and is also present as an impurity in RPR. If a deficiency is identified, it can be supplied in the form of zinc sulphate: as a foliar spray (100g/100L) or soil applied (10kg/ha) (refer to relevant organic standards for conditions of use). Zinc sulphate might also be included in compost heaps.

Molybdenum

This trace element has been reported as deficient in 50% of NZ citrus orchards[16] and, apart from its importance for citrus nutrition, it is also needed for the nitrogen fixing activity of legumes. It is commonly applied in pastoral farming to stimulate clover growth. It can also be present as an impurity in limestone. If a deficiency is identified it can be supplied to the soil as sodium molybdate (50g/ha).

Further information about trace elements: Sale, P. (1997). The importance of trace elements for citrus. *The Orchardist, 70*(4): 35-37.

Foliar nutrition

Plants can absorb nutrients through the leaves as well as through the roots. Foliar sprays of fish emulsion are often used to supply extra nitrogen and other nutrients (e.g. potassium and trace elements). Seaweed, humates, amino acids, molasses and compost teas are also used. Supplementary foliar nutrition can be especially useful around the times of flowering and fruitset when the tree's nutrient demand is increased. Foliar nutrition is an effective way to correct a trace element deficiency. Young tissues (i.e., young leaves, growing tips, flowers and fruitlets) absorb nutrients more effectively than mature leaves. Absorption is also promoted by high humidity and daylight when leaf stomata are open. Some materials can cause fruit blemish. Quick drying conditions when sprays are applied, or spraying after harvest, would help to reduce or avoid such damage. It is useful to leave some trees unsprayed to monitor the effect of the spray material on fruit finish as well as for general effects on fruit size, fruit set, etc. This applies not only to foliar nutrient sprays but also to any material sprayed onto the trees.

Microbiological contamination of food is an area of growing consumer concern. Therefore, care should be taken to avoid the use of animal protein based foliar sprays (e.g., fish emulsion) close to harvest. Care would also be necessary with the use of compost teas (e.g., suitable compost materials and process) for the same reason.

Nutrient sprays such as liquid fish and seaweed can have other benefits such as repelling pests and triggering plant defences against pest attack (see Pests and Diseases section).

Soil tests and leaf analysis

Soil tests are used to determine the nutrient reserves held in the soil, monitor long-term trends in soil fertility and help design soil management programmes. NZ soil testing laboratories use tests that have been standardised and calibrated for NZ conditions. Some points to note: there can be considerable variation between soil test samples taken from different locations or times from the same field; nutrients shown to be present by soil tests are not always available to plants; standard soil tests don't usually indicate the availability of organic forms of nutrients such as nitrogen and sulphur that are likely to be more important in organic farming systems; nor do they measure the biological activity which largely controls nutrient availability in organic farming systems.

When sampling, soil should be taken from the same depth as the main tree feeder roots. Also be mindful of differences that might occur between the tree lines and the inter row strips as a result of compost and other soil treatments. Soil can also vary widely within an orchard – look for different topographical features: humps, hollows, terraces; wet spots; markedly different vegetative growth in the sward and/or trees; and different sward species. Collect up to 40 individual samples to mix and make up one representative sample for any particular area.

Where production levels justify the cost, soil testing should be done annually, at least until a balance in nutrient levels is established. The results should be carefully filed for long-term monitoring. Soil samples can be taken at any time of the year but successive tests should be done at the same time because of seasonal fluctuations in nutrient levels.

The pH of orchards can be measured with colour indicator strips, pH meters or as part of routine soil analysis undertaken by soil labs.

Leaf analysis allows the nutrient status of the trees to be compared to optimum levels for the variety. They give an indication of how well the tree is managing to obtain nutrients. Leaf analysis allows nutrient deficiencies to be recognised before visible symptoms appear and productivity has been affected. However, there is not necessarily a correlation between levels of nutrients in the soil and levels found in leaves. For example, a soil test showing low Olsen P (standard measure of P in NZ) might still have high foliar levels of P. This could be the result of an extensive rootsystem and effective mycorrhizal associations. Also, the measurement of close to optimum plant nutrient levels is more difficult than is the detection of deficiencies. Adding to the difficulty is the generally inadequate comparative data; optimum levels in one locality and with one rootstock/scion combination might not be optimum in a different soil and plant combination. Despite these limitations, leaf and soil analysis interpreted along with historical records (analysis and orchard performance), are still valuable tools for growers. They help to achieve good crops, build healthy soil, select the most efficient nutrient inputs and can detect deficiencies (or excesses) before productivity is seriously impaired.

The youngest fully developed leaves on current season's non-fruiting, non-branched shoots from unshaded positions around the canopy and from a uniform medium height (e.g. 1.5 m on mature trees) should be collected. Different aged trees and rootstock/scion combinations should be sampled separately. The sample should include 100 leaves randomly selected from 20–50 trees in an area up to 2 ha(17). Leaves should be washed clean, dried, placed in paper bags and sent immediately to the laboratory. Samples for citrus leaf analysis are usually taken in February–March, although between March and May has been suggested as giving a more accurate indication of tree nutrient status(18).

Visual analysis can with practice be used to determine the nutrient status of trees, although this should complement and not replace, soil and leaf analysis. An experienced eye can distinguish subtle colour differences in plants, which can be early indicators of stress or deficiency. Soil health can also be assessed using a system such as VSA (19). This is an easy-to-use on-farm soil testing system that uses visual assessment to rate various soil quality indicators.

Compost

Compost is the ideal way to add nutrients to the organic citrus orchard. It will usually contain a wide range of plant nutrients and release them slowly for efficient use by the crop. Compost can also add beneficial soil organisms and humus, while at the same time it can improve soil structure. Beneficial organisms fostered in and by compost include fungi and bacteria species needed for important soil processes, such as the formation of humus (humification), as well as anti-pathogenic species that destroy harmful disease-causing microbes (such as *Phytophthora spp*.). Used as mulch or compost it can conserve soil moisture.

Applying un-decomposed materials directly to the soil can have adverse effects. For example, nutrients can be lost when materials applied directly to the soil rapidly release nutrients in excess of what plant roots can take up. Also many materials can produce toxic compounds during the early stages of decomposition that can harm the crop. Raw animal manures can damage citrus tree roots, especially those of young trees. These adverse effects are usually avoided if the materials are first composted. Hot composting can also help to destroy synthetic chemical residues, pests and their eggs, disease spores and weed seeds present in the raw materials.

There are many ways to make compost but, whatever method is used, care should be taken to preserve as much of the nutritive value of the compost ingredients as possible. Nutrients can be lost (especially N) if the pH is too high, insufficient woody material (e.g., hay, bark) is added (C:N ratio too low) or the heap is too wet or exposed to rain. Compost heaps are a potential source of environmental pollution and should be covered to prevent leaching. If leachate is produced it should be recovered (e.g. a contoured base draining into a suitably sized container). Most methods aim to maintain aerobic (aerated) conditions and decomposition processes by periodically turning the heap and including coarse ingredients such as bark or straw. When starting a heap the raw materials should be chopped finely and either thoroughly mixed together or layered thinly. Although composting anaerobically (no air) can reduce N losses, aerobic composting is likely to create a superior microbial profile.

extract (Preparations 502–507) (Table 11). These result in higher composting temperatures, faster compost development and different N characteristics[22]. It is also believed that their use results in a more balanced product that has a higher absorption and vitality rating. Using a wide range of materials helps to ensure the compost contains all the essential elements as well as having a rich microbial profile that will continue the decomposition process (Tables 3 & 4).

Many compost ingredients will tend to raise the pH of the heap. High pH will cause the loss of N (as ammonia) to the atmosphere. For this reason lime should not usually be added to the heap. Composting poultry manure with sulphur (to reduce pH) and straw (to absorb ammonia) can reduce the loss of N[20]. Materials such as straw, bark, peat or zeolite, added to the compost, can absorb N and help to prevent its loss[21]. The carbon: nitrogen ratio (C:N ratio) can give an indication of the maturity of the compost and how much N will be plant available. A high C:N ratio (>30:1) suggests an immature compost likely to cause N immobilisation, while a low C: N ratio (10:1 –20:1) is typical of a properly matured compost with a large proportion of its N likely to become plant available in the first season.

Biodynamic composting uses special herbal preparations to guide the composting process: yarrow, dandelion and chamomile blossoms, stinging nettle shoots, oak bark and valerian

The certified orchard will need to use certified organic materials for composting. Ready-made composts would also need to be certified. Special permission can be sought from the certifying organisation to use non-certified materials. Some indication will need to be provided that such materials do not contain chemical residues or other contaminants. A wide range of waste products is sometimes available and can be used in composting, the nutrient content of some of which are given in Table 4. The amount of compost to apply depends on the quantity of other nutrient inputs, the size of the trees, the planting density and the quality, and availability and cost of the compost. Applications of between 5 and 20 tonnes/ha/yr (12.5–25m^3/ha/yr) are probably realistic for mature orchards. Germination tests using cress or lettuce seeds can be used to determine the maturity of the compost before use. A germination test can be done by soaking a paper towel in leachate from the compost, placing the seeds on the wet towel and placing in a hot water cupboard on a suitable tray. The presence of toxic compounds in the compost would inhibit the germination of the seeds[23].

Table 3. **Important nutrients in some plants used for composting.**
Adapted from Pearce[24].

Plant	Nutrients
Thistles	nitrogen, copper, silicon
Bracken fern	potassium
Comfrey	phosphorus, calcium, iron, potassium, sodium
Alfalfa	potassium, nitrogen, phosphorus
Buttercup	cobalt
Chickweed	copper, boron, zinc, phosphorus, iron
Ragwort	copper
Sorrel	calcium, phosphorus
Inkweed	potassium
Fennel	copper, potassium, sodium, sulphur
Willow	calcium
Blackberry	iron
Broom	magnesium, sulphur
Borage	potassium
Yarrow	sulphur, potassium
Stinging nettle	iron, phosphorus
Gorse	nitrogen
Horsetail	silica, calcium
Banana leaves	phosphorus, potassium
Grass	nitrogen, potassium
Hay	potassium, nitrogen

Table 4. **Important nutrients in some compost materials.**

Material	Nutrients
Seaweed	potassium, sulphur, calcium, nitrogen, iron, plus other trace elements
Fermentation sludges	nitrogen, calcium
Hair, feathers and wool	nitrogen
Wool wastes	nitrogen, potassium, phosphorus
Leather dust	nitrogen
Pea residues	nitrogen, potassium
Wood ashes	calcium (liming effect), potassium, phosphorus, magnesium, zinc
Animal manures	nitrogen, phosphorus, potassium
Basic slag	phosphorus, calcium, magnesium, plus other trace elements
Citrus residues	potassium

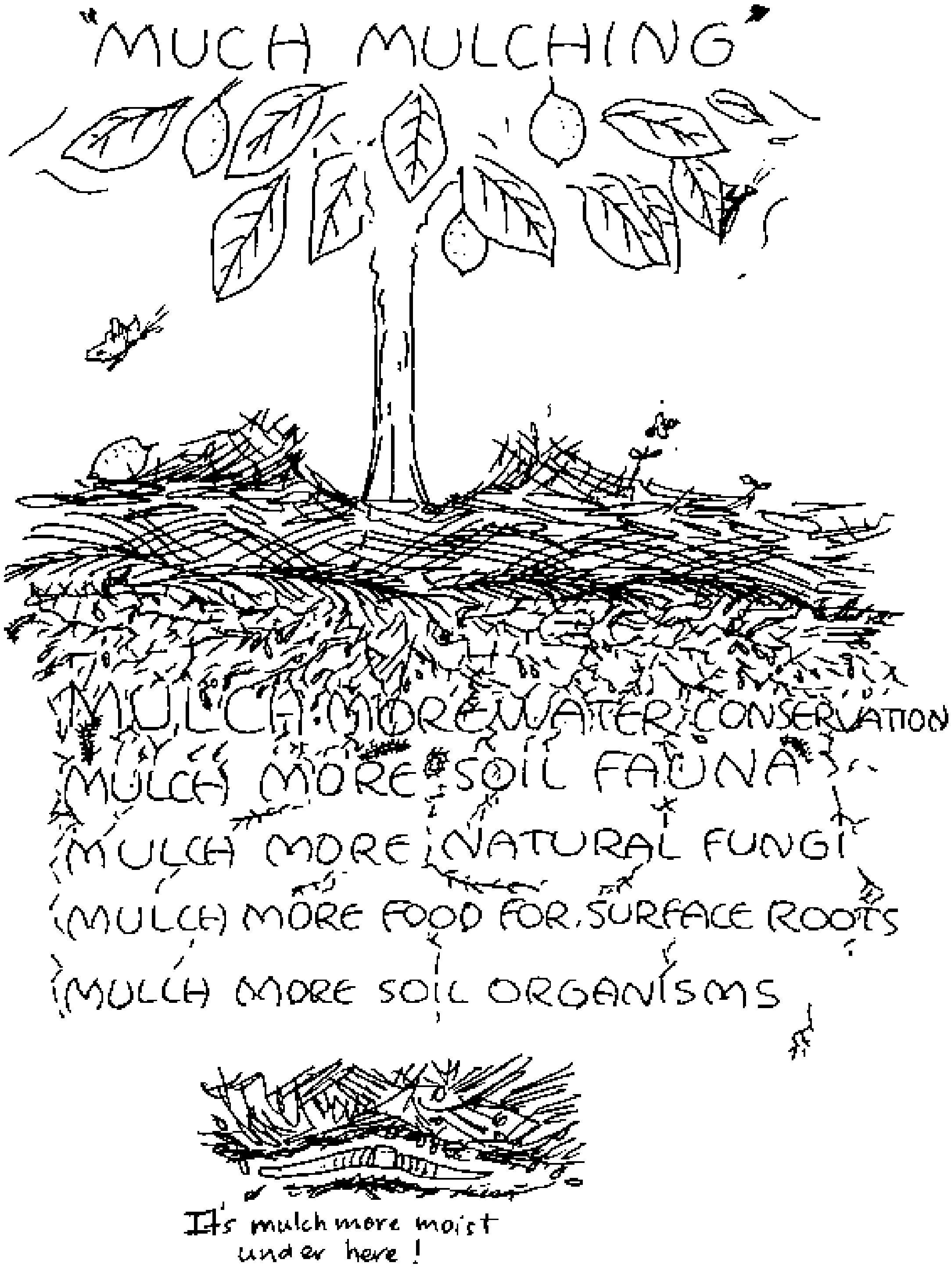
Compost tea can be brewed from compost with greatly increased microbial concentration. This can be applied to the soil or sprayed on to the trees (see Pests and Diseases section).

Vermicompost is made by using worms to process organic materials. Trials on grapevines showed yield increases between 15% (application rate: 10L/m3) and 50% (application rate: 20L/m3) for at least 3 harvests following one initial application. The vermicompost needed to be covered with straw mulch to gain the yield increase[25].

Mulch

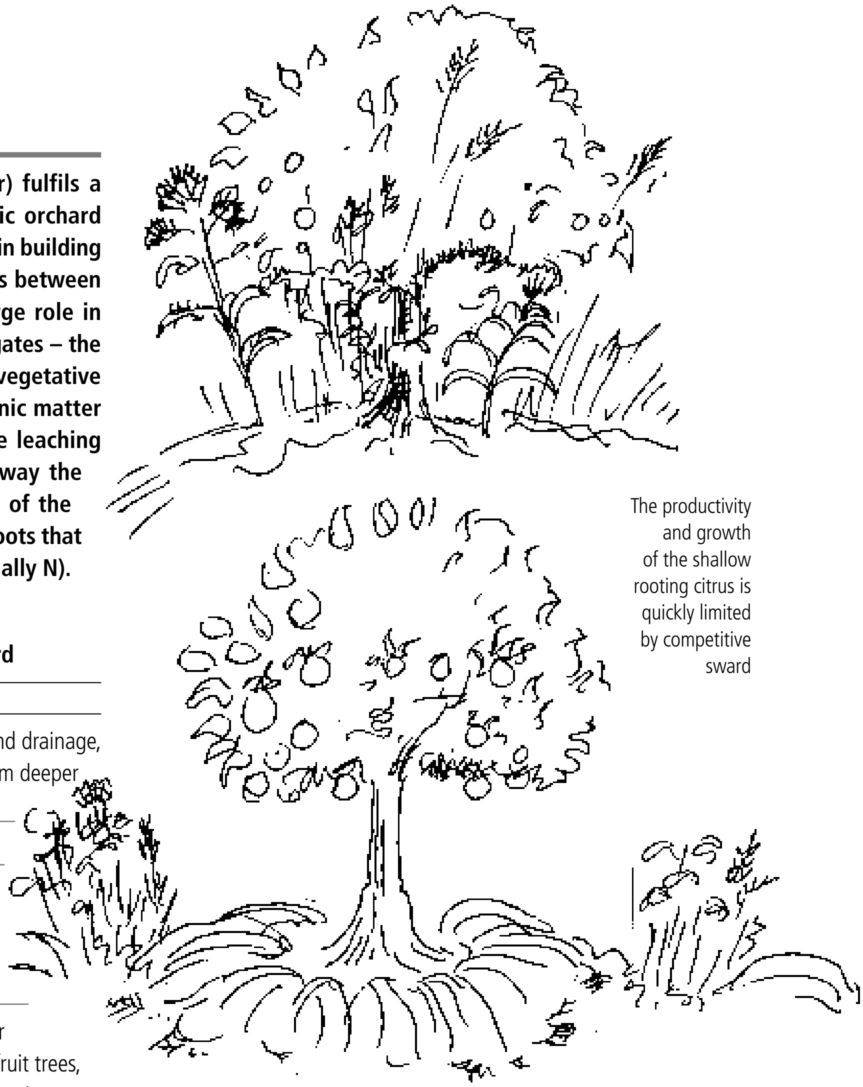
Covering the ground with mulch reduces the rate of evaporation from the soil surface. Placed around the trees, it can maintain moist soil conditions in the tree root zone and by suppressing the understorey, reduce competition for nutrients. Organic mulches add nutrients to the soil as they break down, reduce fluctuations in soil temperature, improve soil structure and increase soil humus content. All of these effects are beneficial for microorganisms and the trees. Mulch can also stop rain splashing disease-causing spores from the soil into the tree canopy (e.g., brown rot). A mulch of wood chips, grass clippings and leaves would be similar in structure and composition to a forest leaf litter to which citrus are naturally adapted. Mulch should be applied to moist soil. If applied to dry soil it could be a barrier to subsequent rain, preventing it reaching the root zone. Excessively thick layers of dense mulch material can cause anaerobic soil conditions and damage the tree roots. Mulches should not contact the tree trunk because they can cause rots to develop in the bark.

Suitable mulch materials include hay, straw, compost, newspaper, grass clippings, gorse chips and aged wood chips. Materials such as hay, straw and woodchips have a high C:N ratio and will tend to be slower to break down and therefore last longer as mulches than materials with a low C:N ratio such as grass clippings, animal manures and composts. Woodiness represents carbon while greenness represents nitrogen. Green materials break down quicker but introduce more nitrogen to the system. Woodchips and other high-carbon mulch materials could cause a temporary soil nitrogen deficiency, especially if incorporated into the soil. In general, the more resistant plant materials will contribute more to humus and soil aggregate formation than those that decompose rapidly. Permanent synthetic mulches are not as suitable because they interrupt the humus forming and nutrient cycling processes in the important rooting areas closest to the tree.



Sward management

The sward (the understorey or orchard floor) fulfils a number of important functions in the organic orchard (Table 5). One of the most important is its role in building soil structure and increasing SOM. Interactions between plant roots, soil and soil microbes play a large role in the formation and maintenance of soil aggregates – the basis of soil structure. The recycling of sward vegetative parts and roots adds large quantities of organic matter to the soil. The sward also helps prevent the leaching of nutrients. This function is related to the way the different root dimensions and growth cycles of the sward species form an interlaced network of roots that intercept and take up mobile nutrients (especially N).



The productivity and growth of the shallow rooting citrus is quickly limited by competitive sward

Table 5. **Sward functions in an organic orchard**

Attribute	Function
Root – soil interactions	Improved soil structure and drainage, gathering of nutrients from deeper soil profiles
Legumes	Fixation of nitrogen
Biodiversity	Ecosystem stability, enhanced soil biological activity – rapid nutrient cycling
Nutrient uptake	Nutrient concentration for increased availability for fruit trees, interception of leaching nutrients
Insect host	Enhanced populations of beneficial insects
Supplementary food for animals	Insect predation (by poultry) and manure, secondary production (e.g. eggs, meat)
Ground cover	Protection of soil from weathering, run-off, erosion, and temperature extremes
Plant material	Source of mulch and means of transferring nutrients to trees, increased SOM

However, the roots of the citrus trees are concentrated in and derive nearly all their nutrient and water requirements from, the same top layers of soil as do the roots of sward plants. Many plant species within the sward can be highly efficient nutrient foragers and therefore are very competitive with other sward plants and more importantly, with the trees. In particular, grass species are among the most competitive of plant species, which is why natural grasslands are usually very stable and durable ecosystems. A point to note about grassland ecosystems is that the total amount of organic matter, both living and stored in soil, is similar to that of forest ecosystems. The difference is where it is stored: in the forest it is mostly above ground; in grasslands it is nearly all below the surface in roots or stored in SOM. The competitiveness of a rapidly growing sward, as is often found after mowing or in the spring and autumn, would be increased. Because fruit yields are not just the product of the current season's conditions but are also strongly determined by the conditions of previous seasons, strong competition from the sward during the current season can depress the yields of subsequent seasons[26].

This indicates the large proportion of the orchard's nutrient pool that can be 'tied up' in the sward. For example, in an orchard where the sward has become overgrown (knee-high or higher) the harvestable vegetation may contain approximately 180kgN, 18kgP and 120kg K per ha. (assuming 6000kgDM/ha). This quantity of nutrients would be likely to represent a significant proportion of the orchard's total plant available nutrients.

Competition from the sward for water and nutrients is perhaps the single most limiting factor in crop productivity and growth in organic orchards.

To gain the benefits of a healthy sward it must be properly managed. Sward competition to the trees is minimised by regular mowing, preferably timed to coincide with the periods of maximum tree uptake or with periods of dry weather when the clippings mulch the surface and conserve moisture. Mowing is best postponed during winter to protect the soil from damage from mowing machinery or heavy rain and to maximise the capture and storage of nutrients by the sward – preventing their loss by leaching. Where the roots of the trees do not extend all the way across the row (e.g. in young plantings), benefit may be gained by directing the clippings to the tree line with a side delivery mower (Table 6).

However, this is not the end of the story. Flowering plants in particular play an important role in encouraging beneficial insects. If there are many flowering plants present before mowing, alternate rows or one side of each row, can be left un-mowed to preserve the flowers. Orchards that are well provided with headlands and other wild areas may already have sufficient habitat to preserve beneficial insect species. Organic orchards may not appear as 'tidy' as conventional orchards with flowering 'weeds' left un-mowed or sprayed, but such areas in reality play an important part in the orchard ecosystem.

Table 6. **Annual inputs of nutrient applied along the tree row (1m band) in an apple orchard.**

Source: Marsh et al,[27].

Treatment	Annual addition of nutrient (g/m^2)			
	N	P	K	Ca
Control: mowing with a mulch mower spreading clippings over the whole orchard floor	5.3	0.3	4.3	1
Pea straw mulch applied to the tree line as a 1m band	40	3	45	70
Mowing with the clippings applied to the tree line only	32	2	26	6

Legumes should be encouraged into the sward. White clover will not fix nitrogen or successfully compete with most grass species if stressed by dry soil conditions. To promote clover, consider irrigating the row centres during summer and apply RPR and lime to the whole orchard floor, not just to tree lines. Regular mowing (mowing height about 5cm) will also encourage clover. Therefore, mowing alternate rows not only preserves flowering plants, but will also help to maintain clover.

Deep rooting species, including chicory and comfrey, may be less competitive with the trees than grasses and can also bring nutrients from deeper soil levels into the orchard system. Other deep-rooted weeds such as dock and carrot weed are also beneficial, (e.g., carrot weed makes excellent mulch; dock breaks-up compacted soil and brings nutrients from deeper soil levels, although it is also host to leafroller). Weeds growing into the trees need to be controlled, although many of these probably have other more beneficial attributes. For example, weeds such as ink weed, nightshade and cleavers are rich in nutrients, can successfully compete with perennial grass weeds and, through root-soil interactions, may have beneficial effects on the health of tree roots. Plaintain readily forms mycorrhizal associations and may encourage their proliferation in the orchard.

Legumes, including red, subterranean and white clover and lotus major, can be over-sown. Herbal leys, manure crops and wild flower seeds can be broadcast in spring or autumn. Many species will need repeated sowings to maintain their presence in the sward. Mowing when seed heads have matured will also encourage the survival of sward species. Comfrey can be introduced by planting root cuttings.

Vigorous perennial grasses, such as kikuyu, are very competitive with citrus trees and can severely inhibit young tree development. However, kikuyu does make good compost and mulch. It needs to be rigorously controlled by close mowing and mulching. When using hay for mulch, beware of introducing kikuyu and other perennial weed species into the orchard. Paspalum can become too dominant in dry summers – irrigation of centres may help to maintain sward diversity.

It is more important to vigorously suppress the sward within the tree row (i.e. within the drip line of the trees) than between the rows (the row centres). In many orchards the row centres are well maintained but the tree rows are left uncut. While mowing the centres might be easier and faster, it will do little to help the trees compete with the sward. This is because the main feeder roots of the trees are found within the area closest to the trunk, and competition from the sward within this area will have most impact on the trees. The sward is usually suppressed by mowing or by mulching. Shallow soil cultivation could also be used, provided care is taken not to damage the tree roots and soil degradation is avoided by compost additions or by allowing the sward to re-establish between cultivations. Other alternatives include flaming and organic herbicides, although the cost effectiveness of these approaches could limit their use. Flaming would be likely to encourage perennial weeds; herbicides would tend to reduce sward diversity (certain species able to withstand the herbicide would dominate).

Mowing

Mowers can be expensive pieces of machinery. However, second-hand mowers can often be bought and reconditioned cheaply. They can also be adapted to better match the orchard's needs. For example, the cheapest mower that will deliver the cut material from the row centres to mulch the tree lines is a standard rotary slasher with one side open for side delivery. Such a machine can be adapted to be offset. Belt-driven triple-spindle mowers are available, including offset and side delivery versions. Mowing machines must be matched to the horsepower of the driving tractor or else either one may be damaged. They must also be suited to any contouring or mounding of rows in the orchard.

Swing-arm mowers are good for cutting the sward close to the trees. A cheaper alternative might be a disc mower, such as are used for cutting hay. Scrub bars or weed-eaters are noisy, can damage the trees and are hard on the operator; a traditional hand scythe can be faster, quieter and much less stressful on the operator. The knack to using a scythe is to pretend you're cutting bread – don't hit it, slice it with a sawing motion; touch up the blade with a stone or file after every tree or so. Self-propelled walk behind rotary or sickle-bar mowers may also be suitable.

Note: Mulching mowers pulverise the sward – good for rapid recycling of nutrients. Sickle bar mowers, scythes and scrub bars leave the cut sward mostly intact – good for a longer lasting mulch effect. Slow speed rotary mowers – intermediate between mulching mowers and sickle bars.

Within the tree lines the sward should be cut as short as possible during the spring, summer and autumn. Within the tree rows the mower can be set depending on how much mulch is needed or what sward species are being encouraged. For example, shorter mowing during early spring and autumn can promote white clover and other low growing or spreading species by reducing competition from the grass component of the sward.

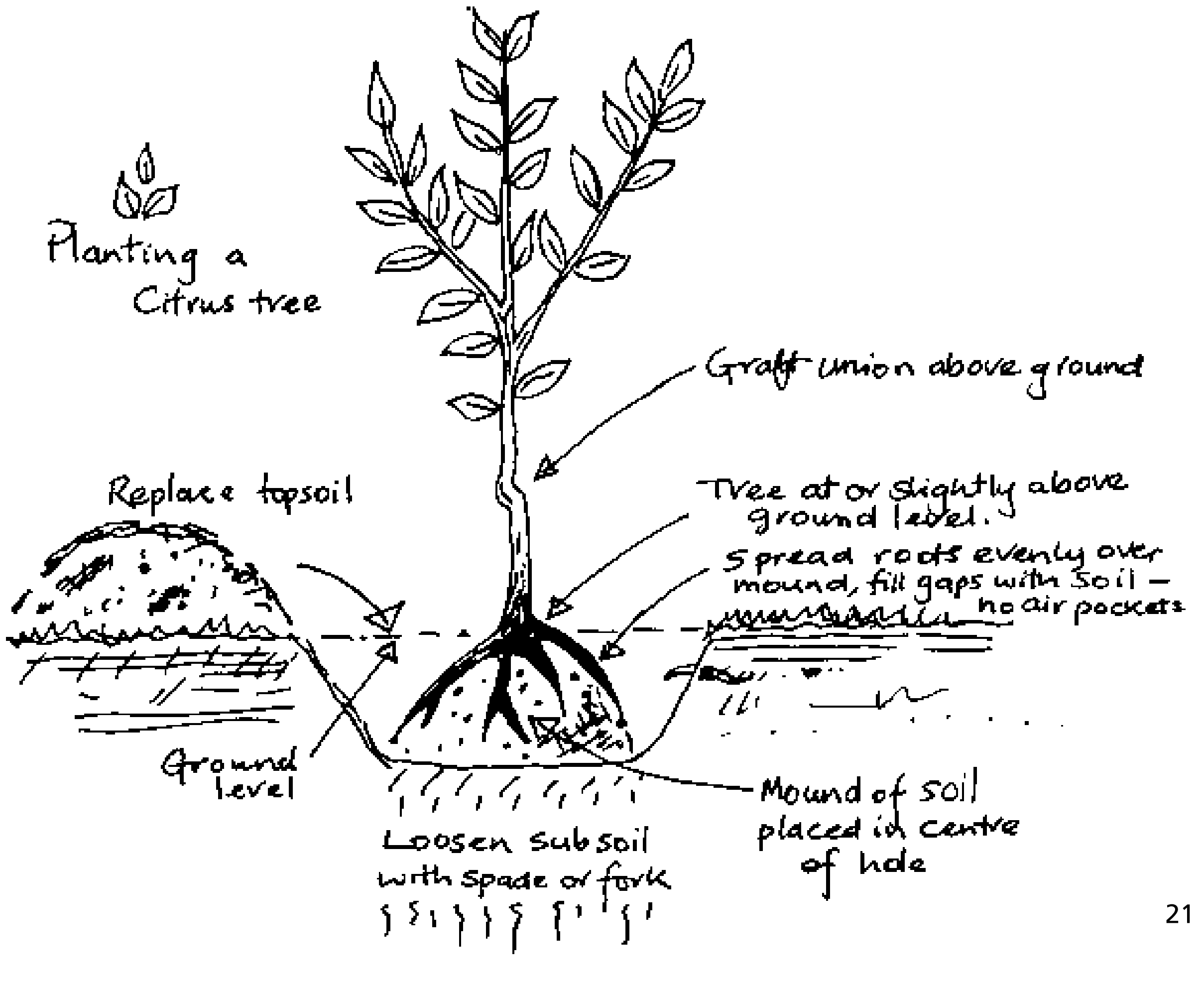
Cutting the sward in early spring with a side delivery mower can allow rosette-forming biennials such as carrot weed to establish and can also expose the surface and allow emerging beetle larvae to be predated by birds.

Tree management

Even in the most fertile soils, citrus trees must be well cared for if good yields are to be sustained. Good tree management begins at planting and continues throughout the life of the tree with regular pruning. Understanding the trees is important for their effective management. Citrus trees, like other higher plants, are highly evolved, complex living beings. They have a multitude of active responses to their environment, including comprehensive responses to injury or disease invasion (an immune system) and actively modify the soil environment to increase the availability of nutrients or to reduce the activity of unwanted elements (e.g., heavy metals). Flowering plants such as citrus can live for decades without expending valuable energy to move around in a search for food or to fulfil other needs. They cleverly get animals including humankind to do tasks for them such as pollination and seed dispersal. It is helpful, therefore, to see the trees in the orchard as sophisticated living creatures and as active partners in the orchard business.

Planting

Organically raised citrus trees are not yet commercially available, but can be specifically propagated for the orchard by



organic or biodynamic methods. Trees are usually planted in autumn or spring when soil conditions are suitable (friability, moisture content and warmth). If it is a new orchard, soil tests can be taken and any deficiencies corrected before planting. A wide, rather than deep, hole should be dug. It can be beneficial to cultivate the ground before planting to kill off competitive perennial weeds and to generally improve the soil physically, (e.g., where there are impervious layers or pans in the soil).

Remove any damaged sections of root. The trees should be set on a mound in the centre of the hole with the roots spread evenly in an untangled radial arrangement over the mound. Fine soil should be worked in between the roots to fill any air gaps. Finally, after all the soil has been returned to the hole, it can be firmed by gentle tramping or by watering. After planting a generous mulch of well-matured compost can be placed around the tree, avoiding direct contact with the stem. Cultivation and cash cropping between the rows can improve orchard establishment. Tall growing crops such as corn create warm and sheltered microclimates around the young trees.

Planting on mounds above the level of the surrounding ground can help to reduce root disorders. Ridging and contouring can assist drainage from the root zone leading to improved fruit quality. However, machinery such as mowers will need to be adapted for the particular contouring configuration. Also a greater degree of planning may be necessary to ensure the ridge layout facilitates surface drainage and does not lead to ponding during heavy rain (K.Pyle, pers. comm.).

Accurate placement of trees in straight rows can reduce the likelihood of later damage by mowers and other orchard machinery. North–south row alignments are generally preferred for optimal light distribution, but sometimes the shape or slope of the land may suit a different arrangement.

The young tree

Fruit should be removed from young trees for 2–3 years to promote canopy development. Fruit from young and rapidly growing trees is often of inferior quality. It is most important to suppress weeds and to maintain a mulch cover around young trees. Reduction of weed competition and maintenance of moist soil conditions will encourage establishment. Mulching will also foster the establishment of mycorrhizal relationships and other helpful interactions with soil organisms.

Pruning

Good pruning practice is based on observations of how the tree is growing. By observing the tree, an understanding can develop of how nutrients and energy are flowing from the canopy to the roots and back into the canopy and fruit (and flowers). Pruning then becomes a precise operation that maintains productive trees. Pruning is a skill that comes with practice.

Pruning removes diseased and unproductive wood, improves light and air movement through the canopy, regulates crop load and maintains the tree within its allotted space. A larger fruit bearing surface and better airflow is possible when canopies are relatively open, rather than dense. Canopies can be continuous hedgerows or discrete trees, although airflow might be better with the latter. Good airflow through an open canopy and the absence of dead wood reduces the build up of pests and incidence of disease. The aim is to have fruit forming on a framework with the most direct connections to the main trunk and supply route of the tree, i.e., the more directly nutrients can move from the roots to the fruit the better.

At planting

Remove any laterals that have steep angles in relation to the main stem or that are emerging below 50cm. Trees should not be headed back unless being trained to open centres (see below – vase shaped trees), as this removes nutrient reserves and photosynthesising foliage important for early establishment. Don’t remove single leaves attached to the stem for the same reason. Unwanted shoots including suckering shoots from the rootstock should be rubbed off to ensure growth is concentrated where it is wanted, i.e., the formation of structural branches.

Free form

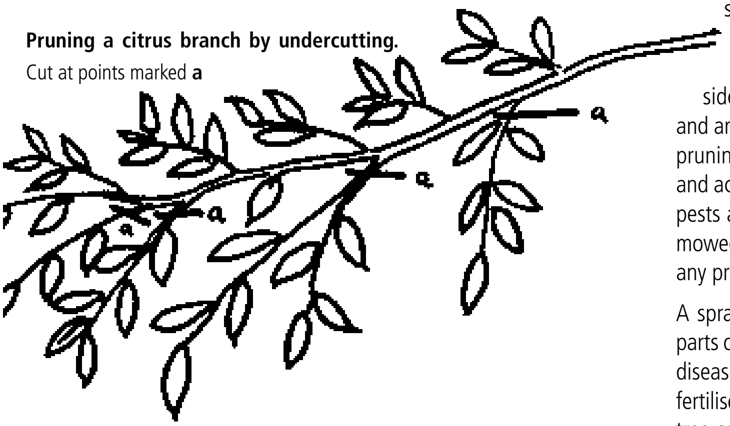
Citrus trees left to themselves can form a rounded canopy that can be quite productive. However, it tends however to become too dense, with all the fruit carried on the outside edge of the canopy. Also branches can be crowded and cross over one another. It is best to select the four to six main scaffold branches during the first few season’s growth and remove unwanted shoots that would lead to overcrowding later. The main branches should emerge from the trunk successively rather than from the same branching point and symmetrically, so that the tree is not lopsided. In the mature tree structural pruning is restricted to removing crossed limbs and thinning major branches where the canopy has become too thick. Branches may also need to be removed in order to lift the skirt of the tree clear of the ground.

Further pruning consists of removing dead wood and cutting out borer damage. Where borer have damaged a major limb, the hole can be explored with a fine hard wire followed by a liberal injection of a neem soap (from Trade Aid stores) or household detergent diluted with water or natural turpentine.

Light should be able to penetrate the canopy but excessive pruning will reduce yields. Define the branches – some separation of branches to allow light and air to move around the branch and to increase the fruit bearing area. The position of fruit relative to the main trunk influences its ability to obtain a plentiful supply of nutrients and water. Therefore, fruiting laterals with the most direct connection or route to the main structure should be selected and the convoluted and much branched laterals removed.

The way to thin the laterals on a branch is to undercut, that is to remove laterals growing downwards from a branch. Often these are the laterals that have been bent downwards by having carried fruit; much of this pruning can be done during harvest by double clipping. Fruitful flowering laterals will grow upwards from the same branch.

Pruning a citrus branch by undercutting.
Cut at points marked **a**



The best time to prune is after harvesting of a light crop ('off year'), when the next crop is expected to be heavy ('on-year'). This helps to reduce the on-year crop, reducing the need for thinning, increasing fruit size and reducing the biennial bearing tendency. Ideally much of the thinning of laterals is done during harvesting by double snipping fruit. This is when the first snip removes the fruit and its lateral – the second snip removes the fruit at the button. By being in the habit of always carrying secateurs when in the orchard, a little pruning can be done here and there at any time. This is a very good way of managing borer.

With vigorous varieties like Encore longer shoots may need to be shortened to reduce the risk of breakage under crop load and to remove the leafless inflorescences that form on the end of laterals that produce fewer and inferior fruit.

Vase shaped trees

Citrus can also be trained to a specific tree shape such as open centred or vase shaped. This system is suitable for mandarins, especially vigorous small-fruited cultivars such as clementine and lemons. Training should be commenced at planting with the heading back of the main stem leaving four or six evenly distributed laterals to become the main scaffold branches. The selected laterals should have wide crotch angles and the lowest should emerge no lower than 40cm from the ground. Subsequent pruning consists of maintaining the dominance of the main structural branches by removing or shortening their laterals. The centre of the tree is kept open by removing strong inwardly growing laterals. By judicious thinning of laterals fruit size can be increased.

Renovation of old orchards

Citrus trees can remain productive for many years and there are even reports of individual trees living for hundreds of years. Where trees have been neglected for some time but still appear strong and basically healthy, they can be rejuvenated by a combination of pruning and manuring. Quite severe cuts can be made and the size of the tree very much reduced, but it is better to carry out such alterations over two or three seasons. In Biodynamic practice, major pruning cuts would be made when the sap-flow is low – just before the new moon. For example, the first year the centres can be cut out and borer damage removed or treated. Major borer damage to the trunk can be sealed up with Polyfiller or mortar. With extra light and the removal of wood there will be a flush of new shoots on the remaining lower branches. The following year the side branches are cut back to some of these new shoots, and any remaining dead wood is removed. In subsequent years pruning should be aimed at maintaining a reasonably open and accessible structure. Prunings are best burnt to destroy any pests and diseases they might contain, and the whole orchard mowed close to the ground with a mulching mower to pulverise any pruning residues, debris and perennial weeds.

A spray of Bordeaux and oil, especially inside on the woody parts of the tree, can help in the removal of lichen and control of diseases. Generous quantities of organic soil amendments and fertilisers should be applied. Compost can be placed around the tree or into trenches dug between the trees, to stimulate new root growth. The orchard should be kept well mowed and the trees kept mulched. If the trees do not respond to this treatment they probably need replacing.

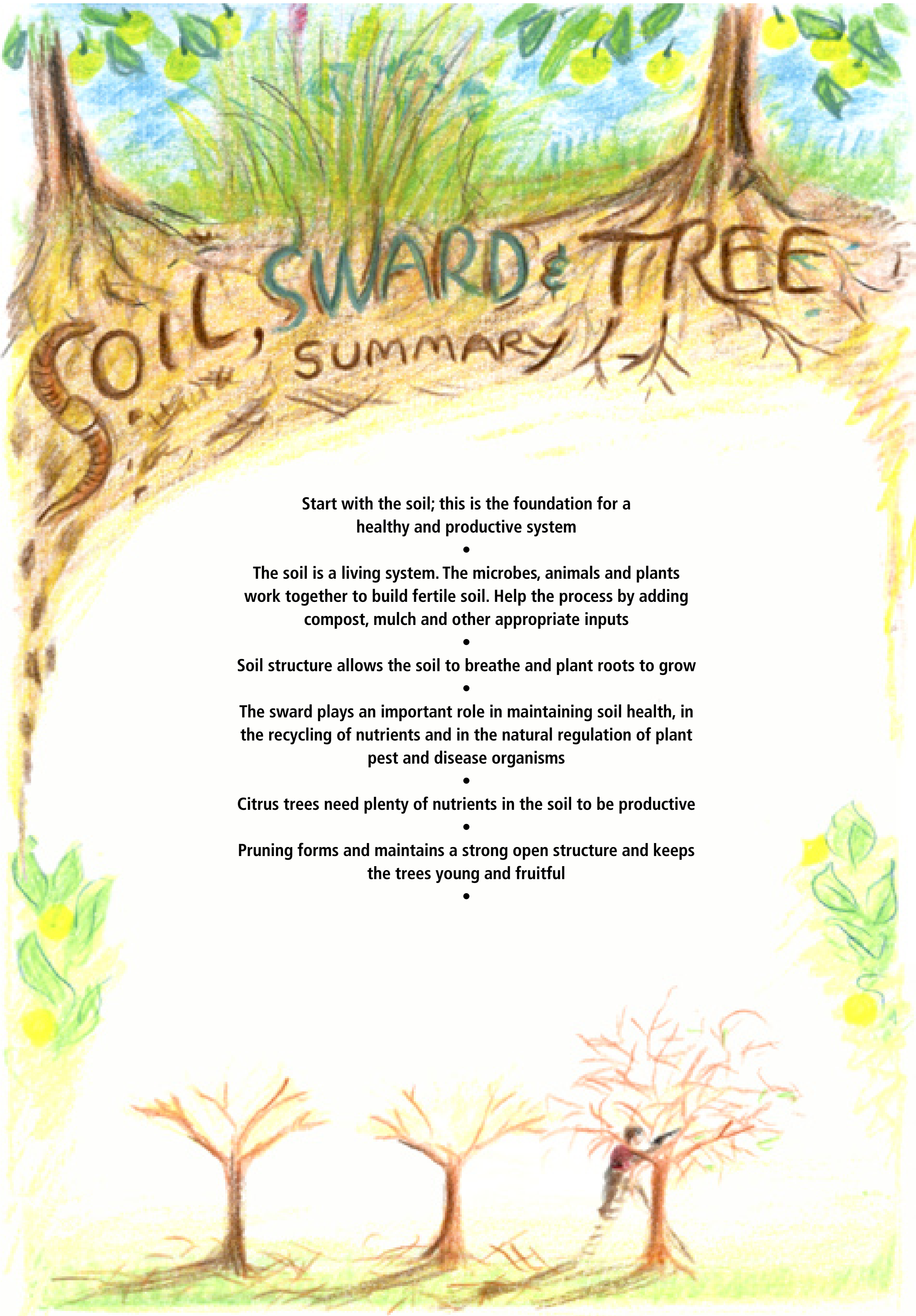
Where orchards have become overcrowded, alternate trees or alternate rows can often be removed to good effect. Many pests and diseases of citrus can be avoided if trees are not overcrowded. If the trees to be removed are cut back the season before removal, the expected short-term reduction in yield can be minimised.

Saw cuts will heal quicker if the edges are trimmed and bevelled with a sharp knife to remove jagged edges. A smooth bevelled edge encourages the formation of callus. All larger cuts should be protected with a pruning paint (e.g. Stockholm tar), grafting wax or a special organic preparation (check certification standards). If using Stockholm tar avoid skin contact. There are several biodynamic recipes for tree pastes but they mainly rely on cow manure (and/or cowpat pit = cow manure fermented with the BD compost preparations) as a base ingredient. Usual additions are clay, like bentonite, to help with plasticising. Other substances that can be used for making the paste stick better are sodium silicate or egg white. Diatomaceous earth (handle with care!) to spike soft-bodied pests could also be added. Basalt meal and powdered seaweed, as well as various liquids like comfrey- and stinging-nettle tea, are used to turn the whole application into a sort of 'fango-pack' for the trees it is being applied to. Consistency varies from a stiff paste, which is plastered on by hand, to a thin slurry that is applied with spray-gear. The thicker the paste and the younger the trees or portions of them it is being applied to, the more readily it will crackle off with movement. The main point is to smother unwanted life forms and to supply nutrients to the trees in a topical fashion.

Time spent pruning gives a good opportunity for close observation of the orchard. Thus pruning can produce more than just neat and tidy trees, but can also lead to valuable insights being gained into the orchard's current condition and needs. In other words, pruning is 'tune in' time.

The pruning kit

Pruning saw, loppers, secateurs, piano wire or similar, paint or grafting wax, plastic squirter bottle and top up container of detergent or soap, and a sharp pocket knife.



Start with the soil; this is the foundation for a healthy and productive system

•

The soil is a living system. The microbes, animals and plants work together to build fertile soil. Help the process by adding compost, mulch and other appropriate inputs

•

Soil structure allows the soil to breathe and plant roots to grow

•

The sward plays an important role in maintaining soil health, in the recycling of nutrients and in the natural regulation of plant pest and disease organisms

•

Citrus trees need plenty of nutrients in the soil to be productive

•

Pruning forms and maintains a strong open structure and keeps the trees young and fruitful

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Compost tea making:

Soil Foodweb Institute Pty.Ltd. 1 Crawford Road, East Lismore, NSW, Australia 2480. Web address: www.soilfoodweb.com

Soil fertilisers and amendments:

A list of sources can be found in any issue of Organic NZ and on the website: organicpathways.co.nz
Fertiliser companies will often supply certified or approved organic fertilisers such as rock phosphate, dolomite, gypsum and blood and bone. Limestone is usually available from local lime quarries. Fishmeal is available from Talley's in Nelson; blood and bone from local freezing works. Availability and price of compost and bark products varies. Local councils sometimes operate or contract out composting operations. Quality, availability, and price vary. Check out local transfer stations or councils (caution: immature compost can be toxic to plants). Your local Environment Centre may also be able to help find materials and information.

Some sources:

Agrissentials (Tauranga) – rock dust, organic fertiliser blends
Agrich Organics (Napier) – fish-bark compost, bark mulch, compost tea
Ocean Organics (Paeroa) – liquid seaweed
Sieber – Moana liquid fish
VITEC Fertilisers - (Tauranga) – liquid fish and seaweed

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Crop management

Successful crops are the result of good orchard management during previous seasons as well as during the current season. Apart from fertile soil conditions and well-planted and -pruned trees, a successful crop also depends on careful monitoring and skilled management throughout the season. Management activities include: regulation of crop loads to avoid biennial bearing and to maintain fruit size, maintenance of soil moisture levels, protection of the crop from pest and disease damage and, finally, the crop has to be harvested and marketed properly.

Growth and flowering

In cool climates such as NZ, citrus have two main growth flushes – one during spring and another in late summer–autumn. The spring flush is both vegetative and floral. The notable exception to this pattern is in the case of lemons and limes that have new shoots and flowers emerging year-round. Root growth will occur whenever soil conditions are favourable. It will be inhibited by low soil temperatures (<13°C), low soil moisture levels (soil water potential <-0.05Mpa), soil compaction and during periods of rapid shoot growth or heavy crop load (competing sinks).

Flowering shoots (inflorescences) grow from buds on laterals that grew during the previous spring or summer growth flushes and can be leafy or leafless. Leafy inflorescences are the most productive, with flowers most likely to set and retain fruit. Most of the common citrus varieties do not require cross-pollination for fruit set and are either self-fertile or can set without any pollination (parthenocarpic). Pollination is mainly by insects.

Flowering in citrus is closely related to the quantity of shoots produced during the previous growth flush, which in turn is largely regulated by the crop load present at the time. A heavy crop, by reducing the number of floral shoots, leads to a light crop the next year, which in turn promotes shoot development, leading to a heavy crop in the third year. The relationship between crop load, shoot development and flowering is the basis of biennial bearing, which can be a problem for citrus growers.

Crop load and biennial bearing

Fruit size is inversely proportional to fruit number and, because size is one of the most important attributes of quality in citrus, setting optimal crop loads is an important management activity. Some varieties of citrus are able to regulate crop load by fruit abscission. Self-thinning occurs mainly in varieties that have large fruit such as grapefruit, which create large nutrient demands early in the season, when fruit is still sensitive to the abscission mechanisms. Small-fruited varieties, such as mandarins, don't exceed the photo-assimilative productive capacity of the tree until later in the season when abscission mechanisms are no longer functional. This can lead to excessive crop loads, resulting in undersize fruit and reduced return bloom. Therefore, these varieties must be hand thinned to maintain fruit size and avoid biennial bearing patterns. However, most citrus cultivars can be biennial in their cropping pattern and will benefit from some thinning in a heavy crop season. Fruit quality in 'off' years tends to be inferior. Thinning has other benefits, including the removal of the protected pest habitat between fruits in tight clusters (thrips, mealy bug, leafroller) and better exposure to sunlight, which increases internal fruit quality.

The sooner thinning is completed after fruit set, the greater the benefit both in terms of fruit size and in the alleviation of biennial bearing. Thinning is usually started following the first natural fruit drop after petal fall (Nov–Dec). Small blemished or misshapen fruit should be thinned first. In the organic orchard it may be advantageous to delay some of the thinning to allow removal of fruit later in the season as blemish and defects appear.

Thinning needs good judgement to remove the right proportion of the fruit. Thin two or three trees to a counted leaf: fruit ratio, and use these as guides to the thinning of the rest of the block. Typical leaf: fruit ratios for Satsuma mandarins are between 20:1 for vigorous cultivars and 25:1 for low vigour cultivars. Thinning of laterals before a heavy flowering and 'on' year is expected can also reduce the crop load and help to alleviate a biennial bearing pattern (see Pruning section).

Fruit growth

Citrus fruit growth has three main stages – cell division, cell enlargement and fruit maturation. The first stage of rapid cell division is concentrated in the peel. Growth rates then gradually slow during the second stage, where growth is focused on development of the pulp and juice sacs and is mainly due to enlargement of the cells formed during the previous stage. The third stage is the period of maturation and ripening, although fruit continues to grow slowly. During this final stage there is a decline in acidity and an increase in sugars, the balance of which contribute largely to the eating quality of the fruit (sugar or Brix:acid ratio). Senescence of chlorophyll pigments in the peel reveals the coloured pigments that give ripe citrus fruit its bright colours.

The number of cells formed during the period of cell division largely determines the final size of the fruit. Cell division in the ovary also occurs before flowering and the initial size of the ovary largely determines the competitive strength of the young fruit. A fruitlet able to compete strongly for nutrients with other parts of the tree will have a longer period of cell division resulting in a larger size potential. Thus, factors that stimulate and prolong cell division, both in the ovary and during the period of rapid cell division in Stage 1, will result in bigger fruit and larger yields. Early thinning of laterals before flowering, optimum tree nutrition and thinning of excess fruit are all important strategies to this end.

Water and irrigation

Compared to many other crops, citrus are efficient water users and are adapted to arid growing conditions. Nevertheless, trifoliata (because of its shallow root system) can be quick to suffer from dry soil conditions. Water deficits reduce growth and can reduce yields. Water deficits during the time of fruit set and early fruit development (October to February) can cause excessive fruit drop and smaller fruit. Water deficits causing reduced growth during the spring growth flush would tend to reduce flowering and crop load the following year. Water deficits during the second stage of fruit development (cell expansion) can reduce fruit size and yield. Productivity is less affected by water deficits during autumn and winter, when fruit are maturing. Reduced soil water at these times can actually improve fruit quality.

Dry soil is unable to support the activity and populations of most soil organisms, including worms. Soil moisture is also directly related to plant nutrient availability and uptake. Soils differ in their water holding capacity. Heavier clay soils will usually contain greater water reserves than lighter sandy soils. Volcanic soils are quick to dry out, while alluvial soils remain moist for longer. Mulching the trees not only adds organic matter to the soil, but also conserves soil moisture by reducing evaporation and weed competition. Mulching can increase tree productivity and growth, reduce the need for irrigation and greatly promote the establishment of young trees.

Water exists in the soil within variously sized soil pores and as a film around soil particles. While water quickly drains from the larger sized pores, it is held by capillary forces against gravity within the medium and small sized pores and on the surfaces of soil particles. The maximum amount of water that can be held against gravity is termed the field capacity of the soil (FC). PAW (plant available water) is the fraction left after drainage and that can be effectively utilised by plants. Irrigation is usually started when 30% – 50% of PAW (the most easily extracted fraction) has been absorbed by the roots of plants or lost to evaporation. Applying more water than is needed to return the soil to FC not only wastes a limited resource, but can also cause nutrients to be leached from the soil.

Regardless of the water holding capacity of the soil, a tree can only make full use of the resource if it has a well-developed root system and if there is not excessive competition from the groundcover plants. Irrigation is of particular importance during the early years of a planting. Inadequate water supplies can drastically slow the development of young trees. Mature trees in many orchards depending on rainfall and soil type do not require a permanent irrigation system.

Trickle irrigation systems, although efficient in terms of water use, usually wet a relatively small fraction of the root system. This can be insufficient to supply the tree's full water needs and can also lead to smaller root systems confined to the wetted area. Trickle systems can also cause problems with nutrient leaching and imbalances. On lighter soils, where there is less lateral soakage, micro-sprinklers or multiple droppers can give more uniform water application than single droppers. At least one third of the root area needs to be wetted for adequate tree uptake. A mature citrus tree can require as much as 48 litres of water per day[28]. Water application at night is likely to be more efficient, allowing water to soak in before being evaporated. Organic matter, although capable of holding more water, can be more difficult to wet when dry.

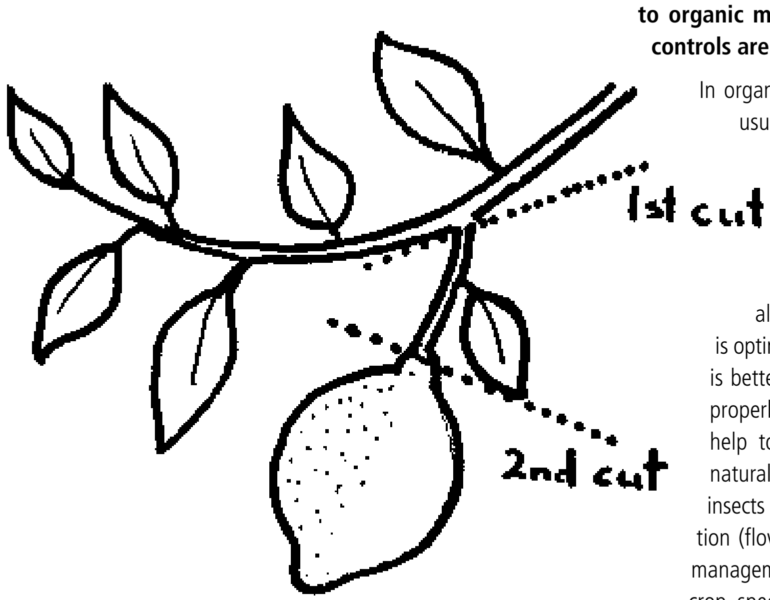
To determine when to irrigate and how much water to apply, soil moisture levels are monitored using a water budget and tensiometers or Watermark™ sensors. Water budgets track changing soil moisture levels by recording estimated daily evapotranspiration (evaporation from all orchard surfaces plus plant transpiration) and water inputs either as rain or irrigation. Data for the water budget are usually available from local bodies such as regional councils. These data are then adjusted to allow for the actual evapotranspiration of the crop and should be supported by soil moisture readings with tensiometers placed at two soil depths around the orchard (one in the main root zone and one just below this zone, but above any pan or gravel layer). The budget shows when PAW has reached a pre-determined level of depletion for irrigation to be initiated and also shows how much water needs to be applied in the irrigation to restore soil to FC. Only sufficient water to bring soil to FC should be applied to minimise the likelihood of leaching and to conserve the water resource.

Application rate should not exceed the infiltration rate of the soil. A micro-irrigation system with micro-sprinklers or jets obtaining 60 – 80 % coverage of the main root area should be properly installed. The system should be regularly monitored to ensure uniformity of water application.

High standards of hygiene are necessary during all postharvest operations to avoid infection by fruit rotting pathogens (e.g., sour rot, blue and green moulds). Most postharvest pathogens are present in the orchard, so care should be taken to avoid contamination of fruit during harvest from dirt or rotting fruit on the orchard floor. Packhouses and packing lines must be regularly cleaned and sterilised. All damaged and diseased fruit should be removed promptly from the postharvest handling area. Fruit subjected to brush cleaning will need to be waxed to seal damaged peel. Fruit grown properly should need little cleaning (e.g., effective management of sap sucking insects that cause sooty mould).

Harvest

Only properly ripe fruit of good quality should be harvested. The marketing of sour, poor quality fruit doesn't encourage repeat sales. There are Brix and Brix: acid ratio standards set for different varieties of citrus. Satsuma mandarins should not be harvested below a Brix of 8.5 and a Brix:acid ratio of 8:1. Further information can be obtained from the Product Groups of NZCGI. Citrus should be clipped from the tree not pulled. By clipping fruit the 'button' is retained and damage to the peel (plugging) is minimised. Buttons left on the tree are also a point of entry for borer and diseases such as alternaria. Fruit is best double clipped. This removes a generally redundant lateral and avoids stem stubs that can puncture other fruit. Careful handling during harvest helps to extend shelf life by preventing many postharvest problems, such as fruit decay and shrivelling.



Harvesting citrus with a double cut.

Adapted from AG Link HPP 172[29].

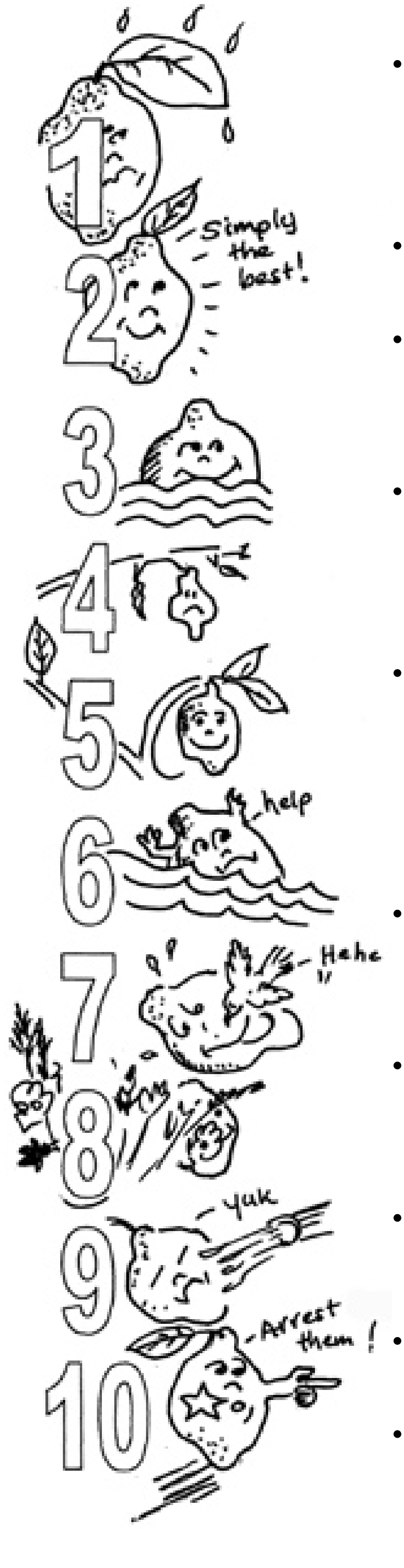
Pests and diseases

A number of pests and diseases can affect citrus trees and fruit. Insects, such as borer, can damage the trees, while other insects, such as thrips, can damage the fruit. Most insect damage to citrus fruit is of a superficial nature, i.e., skin blemish and scarring. Such damage will, however, spoil the appearance of the fruit and generally reduce its market value. Diseases caused by various fungi, such as brown rot, can destroy the fruit and defoliate the trees, while others, such as scab, can seriously scar the fruit and make it unmarketable. Depending on where the fruit is being marketed some superficial damage to the fruit might be accepted. There are also some diseases caused by viruses affecting citrus and these are best avoided by only planting trees propagated from plant material from the NZ Budwood Scheme (see Cultivar section). Some pests are mainly problematic during transition to organic management and until natural biological controls are re-established.

In organic fruit growing it is accepted that there will usually be some damage caused by pests and diseases. Organic orchard pest and disease management is based on the principle that pest and disease damage will be kept to a minimum and below the economic threshold, if the orchard ecosystem is allowed to function properly and if plant health is optimised by optimal soil conditions. A healthy plant is better able to resist pests and diseases, while in a properly functioning ecosystem natural controls will help to prevent pest and disease epidemics. Such natural controls include populations of beneficial insects that are supported by a species-diverse vegetation (flowering plants, etc.). Organic pest and disease management is further assisted by the use of resistant crop species and by a number of other preventative measures outlined below.

The first step in management of pests and diseases in the organic citrus orchard is to create conditions unfavourable to their development.

Ten factors to inhibit and avoid pests and diseases:



- **Avoid sites with excessive rainfall or wind, damp shaded valleys, south facing slopes and old orchard sites that might have toxic levels of copper and other residues from years of chemical sprays. Frost and wind damage can provide entry sites for disease causing pathogens**
- **Plant healthy disease-free trees and avoid cultivars known to be highly susceptible to disease**
- **Promote tree health by building levels of soil organic matter and soil fertility with additions of compost, animal manures and mulch and, where necessary, organic or approved mineral fertilisers**
- **Remove dead wood from the trees. Dead wood is a source of disease spores of melanose, alternaria and glomerella. Spores of these fungal organisms are splashed by rain onto foliage and spread throughout the tree. Dead wood can also harbour eggs, pupae or larvae of lemon tree borer**
- **Prune or remove over-crowded trees or encroaching shelterbelts and cut or trample long grass. Maintain a reasonably open canopy and lift the lower branches off the ground (skirting) by regular pruning. These steps maintain adequate air movement, ensuring rapid drying of foliage and preventing the build up of pests and diseases, such as sooty mould, white fly and scale**
- **Ensure good drainage. Some form of contouring or planting on mounds can allow surface water to drain quickly away. Surface water can damage tree roots, often with fatal results**
- **Encourage insect-eating birds within the orchard by planting mixed shelterbelts. Poultry, ducks, geese and guinea fowl are very effective at reducing pest insects and cleaning up any fallen fruit**
- **Increase shelterbelt, crop and sward diversity and encourage beneficial insects by planting nectar sources – flowering shelter trees and sward plants**
- **Avoid the use of broad spectrum insecticides such as pyrethrum and derris**
- **Identify and remove alternative pest and disease host species from the orchard and shelter belts.**

Biological Control

There are many predator and parasitic insect and spider species living in the orchard and able to control the populations of most pest insects. However, insecticides, herbicides, fungicides, and even road dust from unsealed roads, can easily harm these beneficial species. Many predatory and parasitic insects are very small and are not usually seen. 'Beneficials' can be encouraged by planting nectar- and pollen-producing plants as alternative food sources (needed by the beneficials at some life stages and seasons when pests are not available) and providing habitats (e.g., 'beetle banks').

The larvae forms of some beneficial insects are predators (e.g., hover fly and ladybirds). Other predators include earwigs, harvestman and hunting spiders, ground beetles (carabid beetle), damsel bug, paper and German wasps, praying mantis, lacewings and birds. For a detailed summary of natural enemies of citrus pests in New Zealand see Stevens[30]. Some beneficials, called parasitoids, lay eggs on or in the pest which later hatch and feed on the pest's body. There are also beneficial pathogens that cause disease in the pest.

Plants to encourage beneficial insects and spiders:

Tansy phacelia – parasitoids and predators

Buckwheat – parasitoids of leafroller caterpillars

Cleome and mustard – catchcrops for green vegetable bug

Asteraceae (Compositae) family: chicory, oxeye daisy, thistles, rayless chamomile, dandelions, tansy, sow thistle, calendula, cornflower, sunflower, etc. – parasitoids and predators

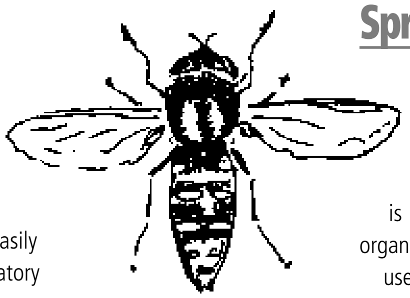
Apiaceae (Umbelliferae) family: wild carrot, wild parsnip, parsley dropwort, stone parsley, fennel, dill, etc. – parasitoids and predators

Tasmanian blackwood, persimmon – host populations of ladybirds

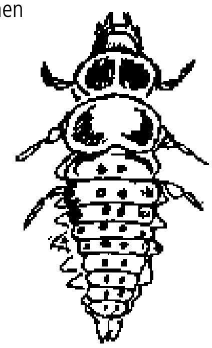
White clover – phytoseiid predators

Wild flowers – parasitoids and predators

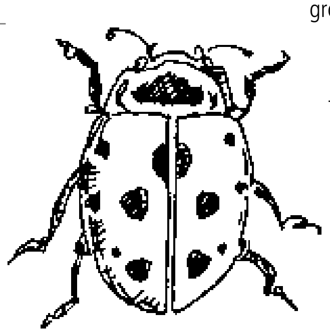
The current development of an IPM programme for citrus (see IPM section) will greatly increase our understanding of biological pest control, as well as showing how populations of beneficial species can be supported and enhanced in the orchard environment. Knowing which specific plant species to introduce into the orchard is probably not as important as increasing overall plant diversity.



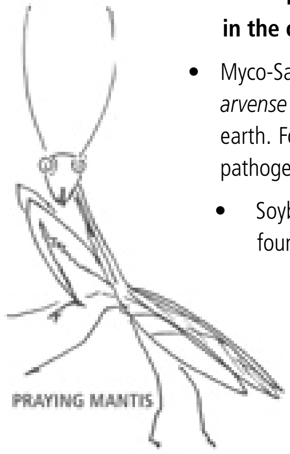
Hover fly ~ Adult



Ladybird Larva



Elevenspotted Ladybird



Spray materials

Sometimes beneficial insects and other natural controls are not sufficient to control a pest or disease organism and some kind of intervention is necessary. There is a range of acceptable natural materials the organic grower can use. Some of these can only be used in a restricted way and with the permission of the certifying body.

Pyrethrum, derris, mineral oil and neem are broad-spectrum insecticides that will also kill or at least reduce the activity of beneficial insects. Mineral oil and neem appear to be the least damaging to 'beneficials', although oil sprays can reduce the sugar content and colour of citrus fruit. Mineral oil sprays are not permitted by Demeter standards. Derris is also potentially toxic to humans. If using these materials it is best to leave parts of the orchard unsprayed to preserve beneficial insect populations. Oil sprays are particularly effective at controlling scale when used at the crawler stage. Fish emulsion is widely used as an insect repellent. It can reduce populations of white fly and scale. *Baccillus thuriengensis* (Bt) is a natural and selective insecticide effective against caterpillars.

The biodynamic Preparation 501, prepared from ground silica, is intended to facilitate the response to cosmic growth factors via the light and warmth forces and thereby helps control rampant vegetative growth as well as susceptibility to bacterial and fungal attacks. Preparation 508 made from the plant Common horsetail (*Equisetum arvense*), which contains high levels of biological silica, is also applied to toughen up the surface of crop-plants and to help balance growth with structure. Silicon has a long history of use for disease prevention in agriculture and its use has recently been revived[31].

Below is a list of potentially useful spray materials that could be experimented with in the orchard:

- Myco-San & Myco-Sin – based on an extracts of *Equisetum arvense* (horsetail), basalt and sulphur or diatomaceous earth. Found effective against both fungal and bacterial pathogens in several crops
- Soybean oil mixed with a spreading agent has been found effective against red mite in apples
- Neem oil or soap – has both insecticidal and fungicidal properties
- Soap based sprays – for example Natrasoap, Protector, coconut soap and homemade soft soap sprays

found to be active against some microbial pests and can also control aphids.

- Compost teas –there is much interest in these as disease preventive sprays. The principle is to inoculate the leaf or fruit surface with a healthy population of microbes. These deny pathogenic organisms access to food resources on the fruit surface essential for their early development and initial infection. There is some promising anecdotal evidence emerging concerning the control of plant diseases by compost teas.
- Seaweed – is widely believed to enhance plant resistance to pests and diseases by improving plant health and eliciting plant defences
- Fish emulsion – as a deterrent to pests
- Hydrated lime – is effective against fungal organisms in crops (e.g. black spot in apples). It is also effective in the postharvest control of brown rot in peaches. It might also have a role in citrus fungal diseases such as brown rot and scab. Hydrated lime is an ingredient of Bordeaux mixture. Other calcium salts could also be tried, (e.g., finely ground limestone, calcium silicate, calcium sulphate (gypsum)). The relatively small amounts of lime used in this way are unlikely to affect soil pH
- Clay powder – has insecticidal or protective properties against a range of pests
- Diatomaceous earth (marine sediments with microscopic needles) **–** is effective against many soft-bodied pests and is generally safe to beneficials
- Repeated drenching sprays of water or dilute seaweed – drown and wash pests out of the foliage
- A thick solution mix of potassium sulphate, hydrated lime and waterglass, with diatomaceous earth, is used by grape growers as a trunk spray to kill lichen and overwintering mealybugs. This could be an alternative to Bordeaux for cleaning up the trunk and main branches of neglected trees
- A badminton shuttlecock can be used as a baited trap. The bottom of the shuttlecock is replaced with a vial containing an attractant (e.g. a mixture of 3-methyl-1-butanol, pentanol and acetic acid) or a pheromone dispenser. The feathers are soaked in a synthetic pyrethroid (permethrin).

When using any spray material leave one row unsprayed as a control and always keep records of rates, conditions and date for future reference and comparison. This is especially helpful when using a new material.

Copper compounds can be very effective fungicides and are permitted but restricted materials in most organic certification systems. Copper is an essential plant and animal nutrient, although only small amounts are required. It can be deficient in some soils, but can also accumulate to toxic levels as a result of repeated fungicide applications. Because of the high spray volumes needed to get complete coverage of the dense foliage of citrus trees, routine copper sprays could lead to excessive accumulation of copper in the soil. Also, copper residues in and on marketed fruit are not compatible with organic consumer expectations. Therefore, copper sprays are not suited to organic citrus production and should not be used except in the most exceptional cases.

The NZ Demeter Certification Standards list wettable copper as a restricted material (a remedy of last resort) with a maximum of 3kgCu/ha/year on permanent crops. No routine spraying is allowed, only prophylactic sprays at known effective times. Monitoring of accumulation in soils may be necessary.

In a mature close-planted block spray volumes could amount to 3750L/ha in a single application. If using a standard rate of copper hydroxide of 150g/100L, this would add 2.8 kg Cu/ha – near the maximum permitted by most organic certification systems of 3kg/ha/yr. This rate of copper hydroxide would apply the same amount of copper as a 2:3:100 formulation of Bordeaux. Even at the rate of 3kgCu/ha/yr, copper could accumulate in the soil to toxic levels over a 50-year period(32).

Rock phosphate and compost are both able to remove copper from the soil solution – preventing plant uptake. Phyto-remediation with copper accumulating plants (e.g. fennel, ragwort, chickweed) might also be possible.

Copper is toxic to earthworms and copper sprays inhibit the activity of beneficial insects such as ladybirds.

Diseases of citrus

For detailed descriptions and identification of diseases refer to the resources listed at the end of this chapter.

Brown rot

Causal agent: *Phytophthora citrophthora* – soil dwelling fungus moves to foliage and fruit from soil by rain splash. Main infection period: late autumn. Control: Improve airflow in orchard and trees, reduce winter shade caused by shelter trees, reduce tree density and cut long grass around trees (i.e., promote rapid drying of foliage). Lift tree 'skirt' by pruning lower branches, apply mulch (e.g., hay or straw) to trees in autumn (before autumn rains), to prevent rain splash from soil. If all else fails apply a preventative copper spray in late autumn.

Melanose

Causal agent: *Diaporthe citri*. These fungi are spread by rain through the tree from infected dead wood. Main infection period: spring to early summer. Control: Remove all dead wood from tree, promote rapid drying of foliage.

Root and trunk rots

Causal agent: *Phytophthora sp*. Control: Use resistant rootstocks (e.g. Trifoliata). Avoid damage to roots and trunk. Plant trees shallow or on raised mounds to prevent wet soil around base of tree.

Scab *(Verrucosis)*

Causal agent: *Elsinoe fawcetti*. Spread to young growing tissues by rain from infections (scabs) on fruit, leaves and twigs. Main infection period: spring to early summer. Control: Plant resistant varieties. Promote rapid drying of foliage. It is important to remove and destroy infected leaves and fruit as soon as they are discovered to prevent any build up of the disease in the orchard. Treat localised outbreaks in orchard with copper sprays after removing visible infections and pruning to open up the canopy.

Alternaria

Casual agent: *Alternaria citri.* Spreads during wet conditions from infected leaves and residual fruit buttons. Main infection period: spring to early summer. Control: Plant resistant varieties. Promote rapid drying of foliage. Always clip-harvest fruit and remove residual buttons in the event of fruit drop.

Glomerella *(Anthracnose)*

Causal agent: *Colletotrichum gloeosporioides*. Spreads during wet conditions. Main infection period: probably early summer. Control: Plant resistant varieties, promote rapid drying of foliage, remove alternative host plants from around orchard (e.g. pine trees).

Sooty mould

Causal agents: *Capnodium salicinum* and others. Grows in 'honey dew' excreted by sap sucking insects including scale, white fly, passionvine hopper, mealy bug and aphids. Control: Improve airflow and light conditions within trees and reduce sap sucking insect populations. Regular fish emulsion sprays.

Botrytis

Botrytris distortion of lemons can be prevented by soap 2% applied monthly[33].

Blue and green mould

Causal agents: *Penicillium digitatum; P.italicum*. Mainly postharvest diseases. Control: Harvest and postharvest hygiene – remove and destroy all damaged fruit, windfalls, etc. Avoid damage to peel during harvest and postharvest handling.

Sudden death syndrome

The sudden decline and death of mature citrus trees on Trifoliata (or citrange) rootstocks can lead to losses as high as 80% in some orchards. The cause is believed to be a number of interacting factors rather than any specific root disease organism. Factors involved include poor drainage and water-logging, damage to the roots or trunk – either by orchard implements or burning by strong fertiliser (e.g. chicken manure), roots not untangled at planting leading to root girdling and trees set in a hollow at planting. The shallow citrus rootsystem quickly suffocates when surface water cuts off the soil air supply. Matt forming perennial weeds such as kikuyu can maintain a water-saturated layer on the soil surface during wet periods. Planting trees on mounds should reduce the risk of citrus sudden death.

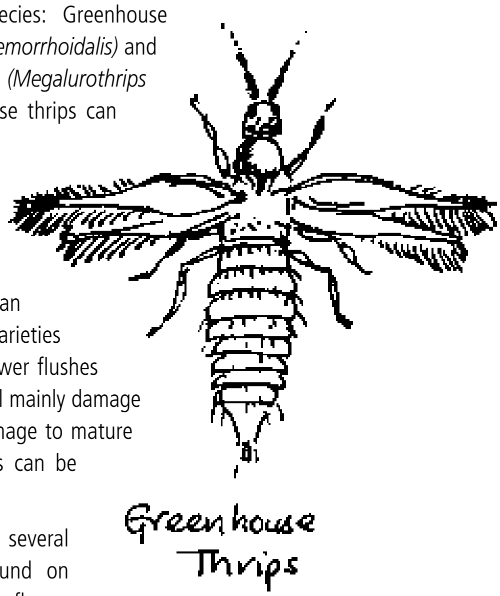
Wind can be the cause of skin blemish and scarring on fruit. In this case, shelter may need to be increased but airflow needs to be maintained.

Insect pests of citrus

For detailed descriptions and identification of pests refer to the resources listed at the end of this chapter.

Thrips

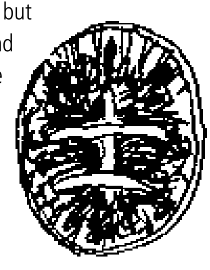
Two main pest species: Greenhouse thrips *(Heliothrips haemorrhoidalis)* and Kelly's citrus thrips *(Megalurothrips kellyanus)*. Greenhouse thrips can build up on leaves and fruit during summer and damage mature fruit during autumn, while Kelly's thrips can build up on citrus varieties that have several flower flushes (e.g., lemons) and will mainly damage young fruits, but damage to mature fruits when it occurs can be severe.



Control: There are several harmless species found on citrus including NZ flower thrips, commonly found on citrus flowers and which may reduce damage by Kelly's thrips by competing for pollen and nectar food sources. A parasitic wasp, *Tripobius semiluteus*, was released in 2001 for the control of Greenhouse thrips. Other beneficial insects helping to control thrips include a very small wasp *(Megaphragma spp.)* and a predatory mite *(Anystis baccarum)*. Oil sprays and soft soap formulations may give some control but are likely to harm natural predators and parasites of thrips. Recent research in Australia has demonstrated the role of various soil organisms, including fungal species, in destroying thrips pupae in the soil. If the species active against thrips pupae are isolated it might be possible to multiply them with using a compost tea machine. Alternative host plants for Kelly's citrus thrips include banana passionfruit, catsear (like dandelion), Japanese honeysuckle, ragwort and creeping buttercup. Greenhouse thrips have a large host range.

Scale

A number of species are found on citrus but soft wax scale *(Ceroplastes destructor)* and Chinese wax scale *(C. sinensis)* are the most common in New Zealand. Scales are more often a problem where broad-spectrum insecticides have destroyed natural biological controls. They might also grow larger and mature earlier when feeding on trees with high nitrogen levels.

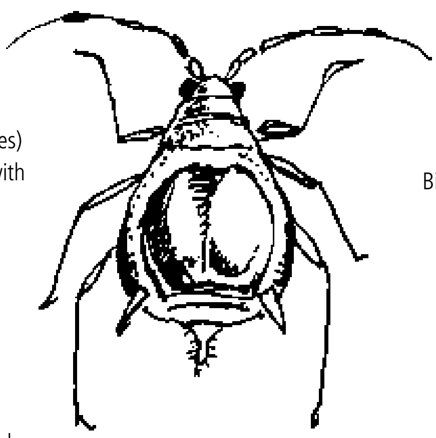


Control: Scales have many natural enemies in the orchard, including the steelblue ladybird *(Orcus chalybeus)*. *Euxanthbellus philippiae,* a small wasp, is a parasite of both common scale species. Other natural controls include birds, bees (borrow the scale's wax), lacewings and other parasitic wasps. They are most vulnerable to predation by ladybirds and to oil sprays (in the case of a heavy infestation) during the crawler stage between November and March. Spraying in the evening may be less harmful to ladybirds that should then be sheltering on the underside of leaves (34). Localised infestations can be removed by pruning.

Aphids

Common species: Black citrus aphid *(Toxoptera aurantii)*

Control: Usually allow time for biological control by predatory insects including ladybirds, hoverflies, lacewings and parasitic wasps. If necessary (e.g., on young trees) outbreaks can be spot sprayed with neem soap, oil or pyrethrum.



Citrus bud mite
(Aceria sheldoni)

Causes distortion of flowers and fruit, especially lemons and navel oranges.

Control: Manage the orchard to foster healthy populations of beneficial insect species. Predators include predatory mites and ladybird and lacewing larvae. Various vegetable oils (e.g., soybean oil) or mineral oil (1%) sprayed in autumn may give control.

Citrus red mite *(Panonychus citri)*.

Damages shoots, leaves and green bark of citrus. Usually infestations are the flow-on effect of broad-spectrum insecticides (e.g., pyrethrum) having destroyed natural enemies, including phytoseiid mites and the ladybird *Stethorus histrio Chazeau.*

Control: Can be controlled by oil sprays.

Citrus rust mite *(Phyllocoptrita oleivora)*

Feeds on the epidermal cells of citrus fruit causing a rusty-brown leathery staining (grapefruit) or silvery russetting (lemons) on exposed surfaces. Badly infected fruit is not marketable. Mainly in the warmer areas (Northland).

Control usually by natural enemies such as phytoseiid mites, etc. Also susceptible to a fungus *Hirsutella thompsonii.*

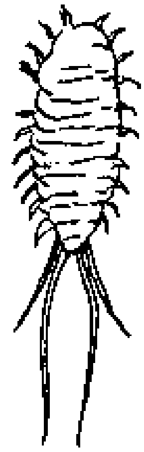
Green vegetable bug *(Nezara viridula)*

Control: Hand picking in early morning when bugs are inactive on exposed surfaces. Foraging poultry are effective predators. Mow vegetation hosting populations during summer.

Mealybug *(Pseudococcus spp.* and *Planococcus citri)*

The main damage is the sooty mould that develops on the honeydew they produce. They are more susceptible to sprays early in spring before the waxy coating develops.

Control: Mealybugs have numerous parasitoid enemies and are predated by lacewing and fly larvae and several ladybird species. A new parasitoid was released in 2001 (*Pseudophycus maculipennis*). Diatomaceous earth and vegetable oil sprays if necessary.



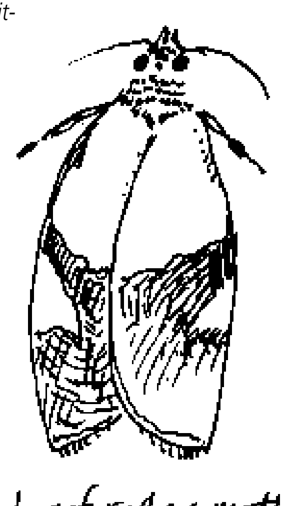
Whitefly *(Trialeurodes vaporariorum)*

Control: Ensure good air movement through orchard and trees. Biological control by ladybirds, lacewings, predatory mites and thrips and parasitic wasps. Fish emulsion and oil sprays can also give some control.

Leafroller

Species: lightbrown apple moth *(Epiphyas postvittana);* brownheaded leafroller *(Ctenopseustis obliquana)*; greenheaded leafroller *(Planotortrix excessana).* Characteristic webbing where fruit and leaf surfaces are touching and within which the caterpillar feeds, damaging the fruit and providing points of entry for disease.

Control: Biological control by wasp and fly parasites, hoverflies, predatory bugs and spiders. Fantails and silvereyes can also eat the moths. Early fruit thinning



to remove touching fruit – a favoured habitat for leafrollers. *Bacillus thuringiensis* (Bt) sprays will kill caterpillars without harming beneficial insects. Pheromone traps are available for monitoring moth emergence. The different leafroller species have specific pheromone baits so identification of the species being monitored is necessary first. Mating disruption, using pheromones, is also possible. Watch for host plants in shelter-belts and adjacent 'wild' areas.

Citrus flower moth *(Prays nephelomima*)

A small moth (3.5–4.5mm long; 8–10mm wingspan) whose caterpillars (pale coloured, 5.5-6.5mm long) attack the blossoms of citrus. Lemons are the most affected. Natural control similar to those for leafrollers.

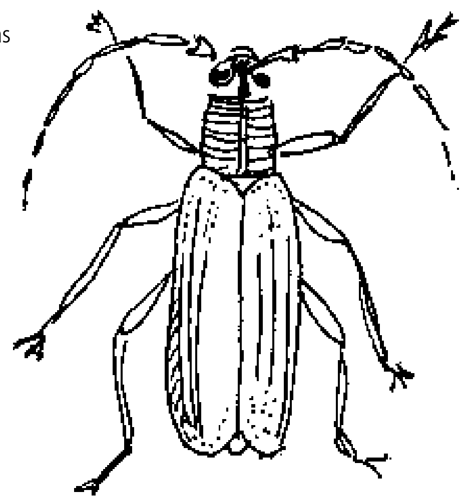
Guava moth *(Cosinoptycha improbana)*

Information about this newly introduced pest species and potential citrus pest can found on the Tree crops website: www.treecrops.org.nz

Lemon tree borer *(Oemona hirta)*

A native beetle that can seriously damage the structure of citrus trees by boring tunnels through the wood.

Control: Prune out damaged laterals as soon as damage appears (wood dust and dying leaves). Treat larger branches, if they are still capable of being productive, and trunks by inserting a wire through the tunnel to skewer the grub and squirting soapy solution (neem soap or household detergent) into the holes. Trim the edges of large pruning cuts with a sharp knife to reduce egg laying sites and cover wound with grafting wax. Biologically controlled in native bush by a number of native species including an ichneumon wasp. Damage to citrus trees might, therefore, be reduced when native trees, especially mahoe, are included in the hedgerows and windbreaks.



Lemon Tree Borer (adult)

Fullers rose weevil *(Asynonychus cervinus)*

A pest of most concern to exporters

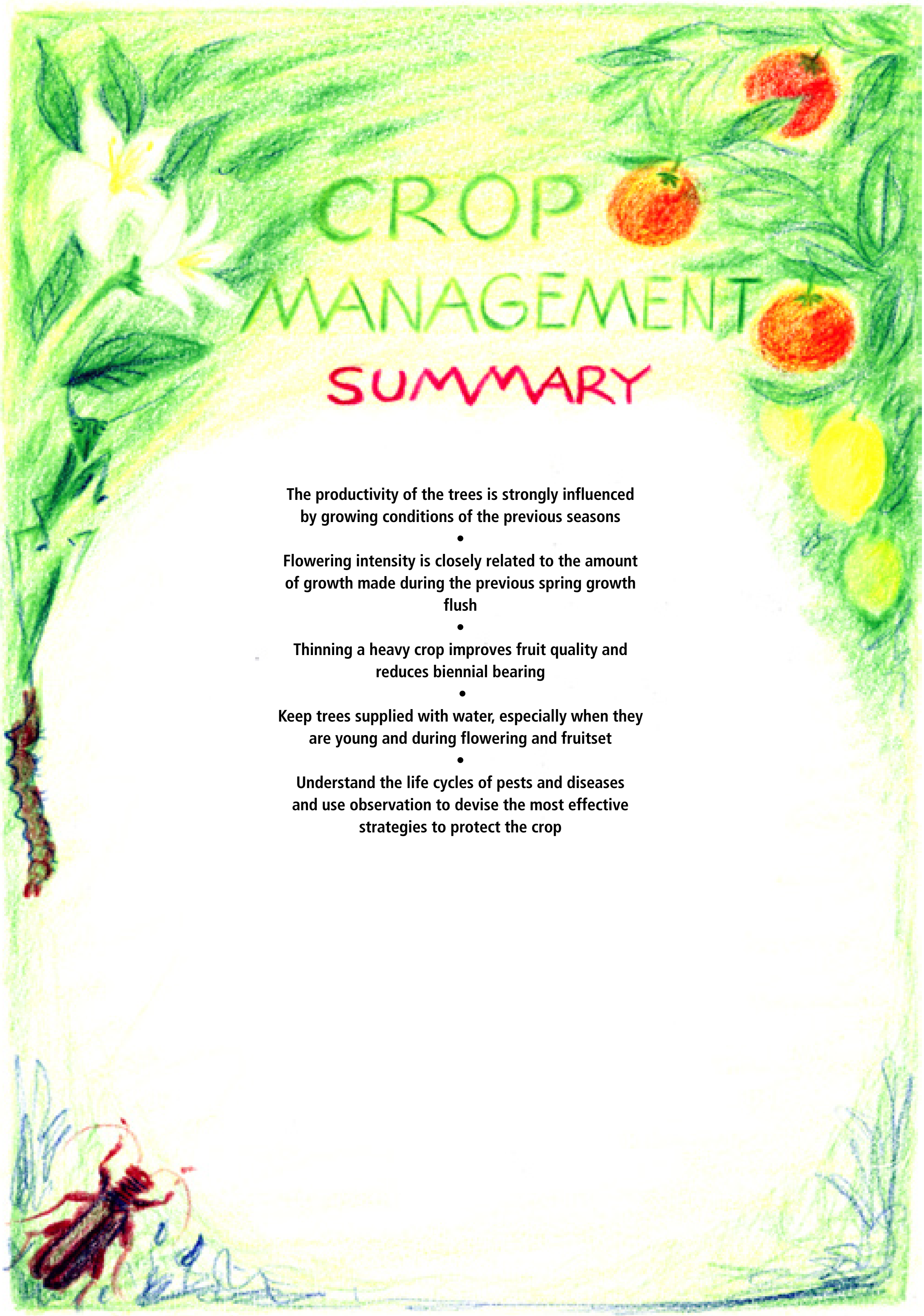
Control: Clear weeds growing into trees, lift tree skirt clear of ground, apply trunk barriers or sticky bands to prevent weevil from climbing into the tree. Biological controls include parasitic wasps, assassin bugs and praying mantises.

Passion-vine hopper *(Scolypopa australis)*

Control: Identify and remove alternate host plants from hedge-rows and windbreaks (e.g., bracken, passion fruit vine). Improve air movement within orchard and trees. Biological controls include parasitic wasps, lacewings, spiders and birds. Sprays of fish emulsion may repel.

Slugs and snails

Control: Sticky bands, Stockholm tar bands. Keep ground clear around trees during autumn and winter. Install resident poultry gangs.



The productivity of the trees is strongly influenced by growing conditions of the previous seasons

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Flowering intensity is closely related to the amount of growth made during the previous spring growth flush

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Thinning a heavy crop improves fruit quality and reduces biennial bearing

•

Keep trees supplied with water, especially when they are young and during flowering and fruitset

•

Understand the life cycles of pests and diseases and use observation to devise the most effective strategies to protect the crop

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Further information on fruit thinning:

Sale, P. (1999). It pays to thin mandarins. *The Orchardist, 71*(1): 42-43.

Further information on fruit thinning, fruit maturity and postharvest practices:

Mooney, P (ed.). (2001). *Growing citrus in New Zealand.* NZ: HortResearch & NZCGI.

Citrus pest and disease sources online:

www.agric.nsw.gov.au/Hort/ascu/zeck/citrus.htm - images of some citrus diseases.

www.hortnet.co.nz/publications/science/kk0995.htm - virus diseases with images. edis.ifas.ufl.edu/ - citrus diseases described and illustrated.

www.wilket.co.nz/cms/default.htm - images of beneficial insects (NZ)

www.wilket.co.nz/cms/ - images of citrus pests (NZ)

www.treecrops.org.nz - some information on guava moth

www.soilfoodweb.com - information on compost teas

Commercial sources of biological controls:

Insects:

BioForce
P.O.Box 812 Pukekohe.
Ph 09 294 8973.
Email: john.thompson@xtra.co.nz

Zonda Resources Ltd
403 Alexandra Street,
Hastings. Ph 06 878 6010.
Email: zonda@inhb.co.nz

Pheromones for guava moth:
Gordon Lees
Ph 09 411 8542.
Email: lees@actrix.co.nz

Wildflowers & herbal leys:
Wildflower World Ltd.
P.O.Box 8161 Tauranga.
Ph 07 576 0470.
Email: info@wildflower.co.nz

Soil bio-innoculants:
Agrimm Technologies Ltd.
P.O.Box 13245 Christchurch.
Ph 03 366 8671.
Email: info@agrimm.co.nz
Website: www.tricho.com

Books with citrus pest & disease information:

J.D. Atkinson (1971) *Diseases of tree fruits in New Zealand.* Wellington: DSIR.

Lucas, R. (1998). *What's that pest – identify and control NZ garden pests and diseases.* NZ.

Mooney, P (ed.). (2001). *Growing citrus in New Zealand.* NZ: HortResearch & NZCGI

Smith, D., Beattie, G.A.C. & Broadley, R. (1997). *Citrus pests and their natural enemies: integrated pest management in Australia.* Queensland: DPI.

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Some brand names of common organic spray materials

Baccillus thuriengensis (Bt) – Dipel, Delfin, Foray, Agree
Pyrethrum – Yates Pyrethrum, BettaCrop Garlic & Pyrethrum
Neem oil – Nemesis
Mineral oil – Sunspray, D-C-Tron
Vegetable oil – Codacide Oil
Clay powder - Surround
Copper hydroxide – Kocide, Champ Flowable, Blue Shield
Insecticidal soaps – Defender,
Pheromone traps – DeSIRe SEX
Herbicides – Interceptor, IT 1

A wide range of organic products available from:

Eco Store, Fruitfed, Town & Country, Wrightsons, Farmlands, Pacific Growers Supplies (Auckland)

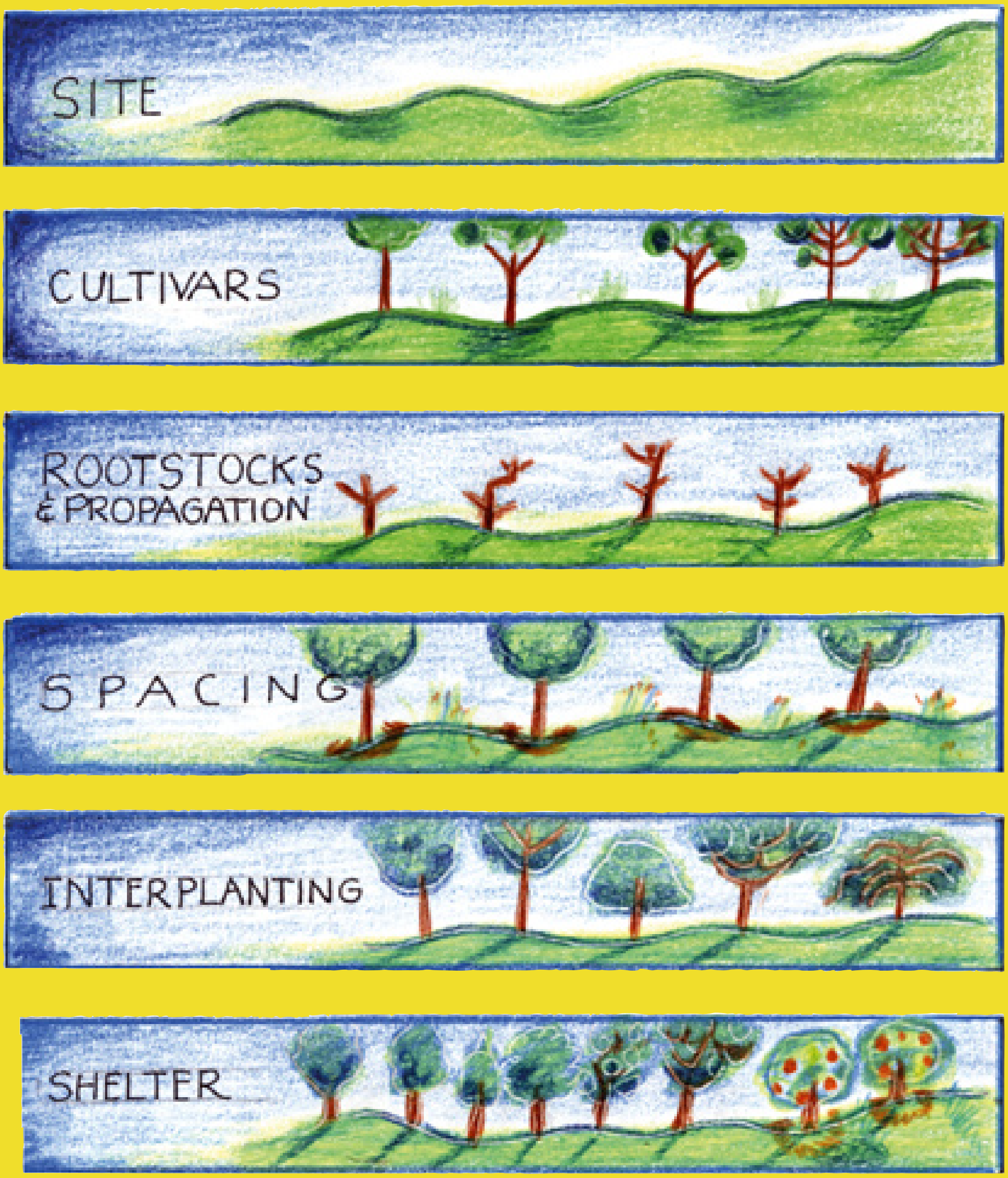
Pest Management Services (Kapiti) - bird scaring devices

Earthwise Direct (Hamilton) – Garlic & Pyrethrum, and other natural pesticides

Table 7. **Articles on citrus pests and diseases in *The Orchardist*.**

Title	Author	Issue
Four wet weather citrus diseases can be conquered.	Sale, P.	Vol 63(8); Sept 1990: 26 - 29
Virus and virus-like diseases of citrus in New Zealand.	Jagiello, C., et al.	Vol 68(8); Sept 1995: 40 - 44
Citrus pests.	Sale, P.	Vol 68(1); Feb 1995: 18 - 2
Citrus pests: part 2.	Sale,P.	Vol 68(2); Mar 1995: 14 - 16
Controlling wax scales on citrus.	Lo, P. & Blank, R.	Vol 69(11); Dec 1996: 34 - 35
Tackle green mould to minimise citrus postharvest losses.	Sale, P.	Vol 68(3); April 1995: 20-22
Citrus thrips: survey results.	Blank, R. & Gill, G.	Vol 71(2); Mar 1998: 47 - 49
Biological control of citrus pests: 1. caterpillar pests.	Tomkins, A.R.	Vol 65(4); May 1992: 24 - 25
Citrus blast and scerotina: two less common diseases of citrus.	Sale, P.	Vol 70(6); July 1997: 47 - 48
Scab: a citrus scourge.	Tyson, J & Fullerton, B.	Vol 73(9); Oct 2000: 64-66
Kelly's citrus thrips 1: effect of temperature on development.	Stevens, P. et al.	Vol 73(9); Oct 2000: 60-63
Kelly's citrus thrips 2: evaluating a potential monitoring system.	Stevens, P. et al.	Vol 73(10); Oct 2000: 60-63
Greenhouse thrips.	Blank, R. & Gill, G.	Vol 70(2); March 1997: 27-29
Kelly's citrus thrips: a tough customer.	Stevens, P. et al.	Vol 71(10); Nov 1998: 58-61
Citrus sudden death	Harty, A.	Vol 69(11); Dec 1996:40-41
Fungicides and insecticides disrupt predation by ladybirds on citrus	Lo, P. & Blank, R.	Vol 65(10); Nov 1992: 14-15
Oil spray results: a must read for growers	Anon.	Vol 74(10); Nov 2001: 65
Changes affecting mite pests of citrus	Sale, P	Vol 75(1); Feb 2002: 40-43
Citrus flower moth a major concern for lemon growers	Sale, P.	Vol 76(3); April 2003: 48-50
Deliver us from weevil	Logan, D.	Vol 76(6): July 2003: 44-45

Orchard design



One of the challenges facing organic growers is to design the orchard so that it can be managed organically with the minimum need for external inputs or drastic interventions such as the use of pesticides. The orchard should be designed for successful integration with the wider local environment.

Site selection

Citrus can adapt to a wide range of soil types providing they are well drained. Less fertile soils will require larger quantities of nutrients to be supplied. Citrus thrive in warm, sunny, sheltered sites that are not subjected to heavy frosts. Sites exposed to high or constant wind are unsuitable, unless effective shelter can be provided. It might also be best to plant shelter several years before planting the orchard.

Land value is also a factor in site selection. Requirements for return on capital or high debt levels can demand levels of productivity that might be difficult to achieve under organic management.

Organic growers are like pioneers and are often required to step out into unknown territory to manage orchard cultural issues. This is because the best ways to manage fruit crops organically are still being discovered, mostly by trial and error in the field. Organic production will also benefit from the large amount of research now being done internationally and in New Zealand for the integrated fruit production (IFP) and pest management (IPM) programmes (see IPM section).

Biodiversity

Encouraging a greater number of species of plants and animals into the orchard may increase the stability and resilience of the ecosystem. A wide range of sward, shelter and crop plants helps to maintain a diverse population of beneficial insects and other organisms, both in the canopy and in the soil. In the soil, biodiversity helps to maintain the recycling of nutrients as well as protecting against root pathogens. The root systems of different plant species act together to prevent the leaching of nutrients. A high level of plant biodiversity fosters a correspondingly diverse microbial and insect diversity, reducing in turn the number of empty niches available for colonisation by pest organisms. Soil health, and microbial and plant diversity, are closely linked.

Interplanting citrus with other fruits would increase biodiversity and break up continuous canopies of a single plant species (monoculture) that tend to attract pests and diseases. As citrus trees have shallow feeder roots, species with a deeper rooting habit might be suitable for interplanting (e.g., peaches or plums). The deeper root systems of interplanted trees are able to capture and utilise nutrients that have leached down beyond the reach of the shallow citrus roots. Native vegetation, including self–sown seedlings within the tree rows, can bring beneficial plant-soil interactions and have positive effects on the orchards' insect communities. While interplanting might make management more difficult in larger orchards, the practice could be a successful strategy in small orchards, where routine crop-specific sprays are less common.

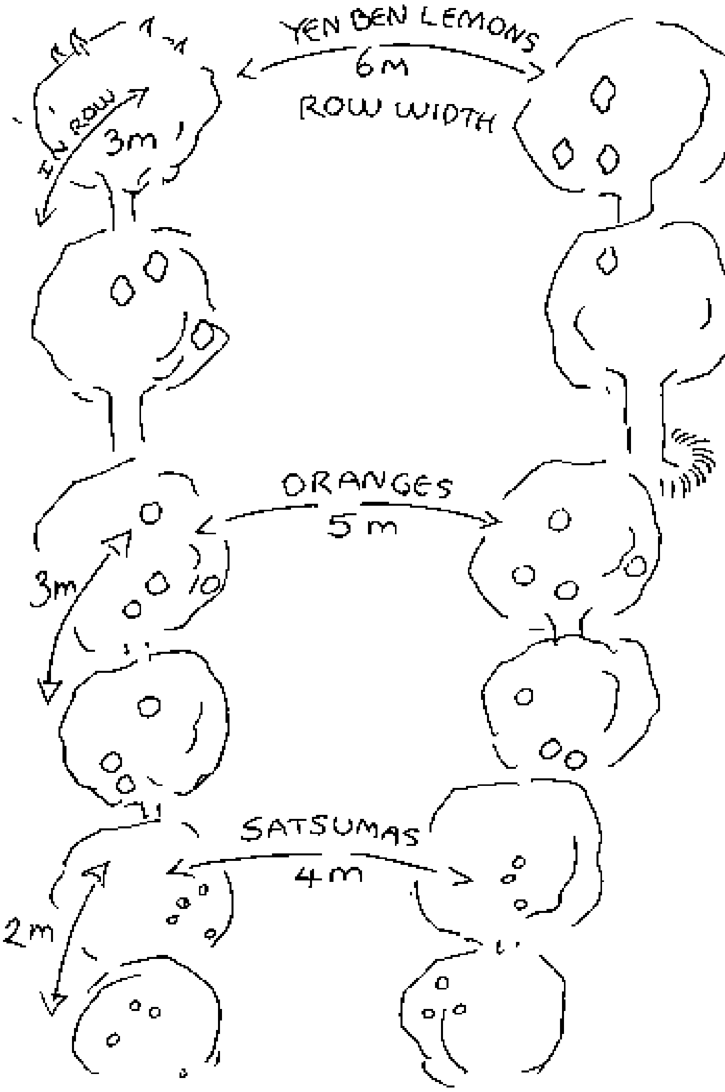
Mixing some citrus varieties can result in cross-pollination and seedy fruit. Varieties susceptible to seediness due to cross-pollination are NZ grapefruit, clementine mandarins, tangelo, Harward late oranges, Encore mandarins and Yen Ben lemons. Varieties most likely to induce seediness include tangelo, NZ grapefruit, Encore mandarin, Richard's Special mandarin, Sweet tangor and Seville orange[35].

Tree spacing

Wider tree spacing in an organic orchard would help to maintain air movement to promote quick drying that would reduce pest and disease pressure. However, increased competition from the sward (a common feature of organic orchards) and the resulting reduction in average tree size might have the same effect. If spacing is to be increased, wider row widths, rather than in-row spacing, might be better because of the increased quantities of mulch that could be harvested from the row. Row widths could be increased from between 0.5 – 1.0m over those used for equivalent conventional plantings.

There is no set tree spacing for citrus but rather tree spacing should be matched to rootstock/scion vigour and soil type. Small growing cultivars like Satsumas are usually planted at 4m x 2m, Yen Ben lemons at 6m x 3m and oranges at 5m x 3m.

Although trees on Trifoliata rootstock are slow growing, they do eventually become large trees. This can result in long delays of up to 10 years before the trees fill their allotted spaces, or alternatively can lead to overcrowding if trees are planted more closely to increase early production. High early production greatly increases the profitability of the orchard. Double planting, with alternate trees removed as allotted spaces are filled, is one way to increase early production and avoid overcrowding later. For example, an in-row spacing of 1.5m can be increased to 3m with tree removal. Row widths of at least 5m will provide plentiful mulch material to young trees and still permit reasonable access to mature trees. Another system would see the row direction changed perpendicularly so that an initial planting at 4m x 3m becomes 6m x 4m with alternate tree removal. Problems associated with close planting could to some extent be managed by regular pruning to maintain an open canopy.



Selection of the optimum planting density is a difficult undertaking and usually ends up being a compromise between high early production and long-term management of tree size.

Cultivars

Citrus species are thought to be native to South East Asia and have evolved in subtropical forest ecosystems with a leaf-litter mulch covering a shallow root system. Records of citrus cultivation go back to 2200BC in China. Common citrus varieties include oranges, tangelos, limes, lemons, grapefruit and mandarins. Because citrus hybridise freely, new fruit varieties are still appearing. There are also some wild fruits from the citrus family that may be adapted to cultivation. For example, there are several native Australian species now being grown in small amounts and being used in breeding programmes[36]. The main varieties grown in New Zealand and some of their characteristics are given in Table 8.

Bud wood scheme

A system to ensure trees of high quality are available to growers was established by the New Zealand Fruitgrowers Federation and HortResearch, and has been supplying budwood selected from superior strains of the main commercial cultivars to citrus propagators since 1992. There are three categories of budwood: Category A are newly released cultivars or breeding selections in high demand and are virus free; Category B are viroid free strains of standard cvs.; Category C are non-indexed but superior clonal selections.

Natural mutations are relatively common in citrus and can appear as 'sports' originating from a single mutated bud on a branch. The effect will be fruit on wood that develops from this bud being different in some way from the rest of the tree. Many important fruit cultivars have been originally discovered as sports (e.g., Cutler's Red, a red-skinned strain of NZ grapefruit, and Yen Ben lemon). It is worthwhile looking for such variations within citrus orchards; disease resistant sports could be of benefit to organic citrus growing.

Table 8. **Main citrus crops and cultivars in New Zealand.** After Mooney[37].

Type	Cultivars	Maturity	Comments
Navel oranges	Washington Parent Navel Navelina and Newhall Cara Cara Johnson's Navel Navelate Summer Navels	July – late Oct " " late June – Oct July – Oct July – Sept mid-July – Dec Aug – Dec	Major navel cultivar Virus free strain, larger fruit, better and more consistent yields Early Pink pigmented Large juicy fruit Late Late
Common oranges	Valencia Harwood Late	Late Nov – March " "	Small but juicy fruit NZ strain of Valencia
Pigmented oranges (blood oranges)	Moro Tarocco	Sept – Oct " "	Red flesh Easy peeling, high quality flavour
Sour or bitter oranges	Seville	July – Sept	Used for marmalade
Satsuma Mandarins	Miyagawa, Miho, Okitsu	mid-April – July " "	Early
	Silverhill Dobashi Beni	Late May – July " "	Standard cultivar New, improved colour
	Kawano	July – Aug	Vigorous tree, good quality fruit
	Aoshima	July – early Aug	Reputed to have good fruit quality – unproven
Other mandarins	Clementine	mid-June – Aug	Sweet, high colour & flavour, susceptible to seediness and scab
	Richard's Special	September	High quality, large fruit, some cultural problems
	Encore	Oct – early April	Long season, summer mandarin, good flavour, can have poor appearance
Tangelos/tangors	Seminole	late Sept – Dec	Standard cultivar, sweet, juicy, high colour, but susceptible to alternaria
	Kiyomi	late Aug – Sept	New cultivar
	Ugli	late Oct – Dec	Good fruit flavour and size, easy peel, puffy
NZ Grapefruit	Golden Special	Sept – Dec	Main strain & cultivar
	Culter Red	Sept – Dec	Pigmented sport of Golden Special
Other grapefruits	Chironja		Orange/grapefruit cross, good fruit appearance and flavour
	Star Ruby		A true grapefruit, pink pigmented, for the warmest sites only
Lisbon lemons	Yen Ben	mid-June – late March	Main export cultivar Lemons are susceptible to scab
Eureka lemons	Villafranca	April – July	Less thorny tree but thicker skinned fruit
	Genoa		Good yields
Lemon hybrids	Meyer	June – Nov	Less acid fruit, hardy tree, some fruit most of year
	Lemonade	July – August	Pleasant flavour
Limes	Tahiti lime	May – July	Superceded by Bearss
	Bearss lime	May – July	Heavy yields, larger fruit

More detailed descriptions of the cultivars listed and of many others that have been tried in New Zealand, are found in a number of Orchardist articles (Table 9). See also Mooney[37].

Rootstocks

A healthy fertile soil promotes the development of a strong and extensive rootsystem, able to grow through a large volume of soil obtaining nutrients and water, as well as anchoring the tree. Citrus trees like most other fruit crops are grafted onto selected rootstocks that are resistant to root disease, give good fruit quality and have a high cropping efficiency.

Trifoliata *(Poncirus trifoliate;* Trifoliate orange) is the most widely used rootstock for citrus in New Zealand and its introduction in the 1950s marked a turning point for the New Zealand citrus industry. This small, thorny, deciduous shrub from central and northern China is extremely cold hardy, is resistant to *Phytophthora* soil diseases and citrus tristeza virus and produces good yields of high quality fruit. However, it does have some limitations such as small fruit size, high fruit acidity and slow tree growth. High fruit acid has limited the development of an export industry for Satsuma mandarins and slow tree growth means that canopy development and time to full production can take a long time. However, trifoliata remains the only proven citrus rootstock for New Zealand. Flying Dragon is an extremely dwarfing strain of trifoliata and is seldom used here. Sweet orange is used for lemons other than Yen Ben and Meyer.

There are several promising alternative rootstocks emerging from trials, such as Benton and C-35 citranges, that are being included in some new plantings. They are mostly hybrids between common citrus cultivars and trifoliata (citranges) and are more vigorous, precocious and the fruit has lower acidity than trifoliata. The extra vigour of these stocks may be useful to organic growers as a way to manage the extra sward competition in organic orchards. For navels and satsumas, C-35 shows most promise, while for lemons Benton and Brazilian sour orange may be worth trying. *The Orchardist* and the NZCGI publication *Citrus News* have regular articles updating trial results for these new rootstocks (Table 10).

Propagation

Citrus trees are usually propagated by budding scion buds onto seedling rootstocks. Grown on their own roots, most citrus cultivars would perform poorly, especially in New Zealand. This is mainly because of their susceptibility to root diseases and poor adaptation to our cooler growing conditions. Early plantings were grafted onto sweet orange seedlings but were susceptible to *Phytophthora* root rots, which caused large numbers of trees to die.

Seeds for rootstocks should be obtained from reputable sources. Citrus seedlings need to be carefully selected to avoid inferior off-types. Scion wood should also be from an approved source, preferably the NZ Citrus Budwood Scheme.

Windbreaks

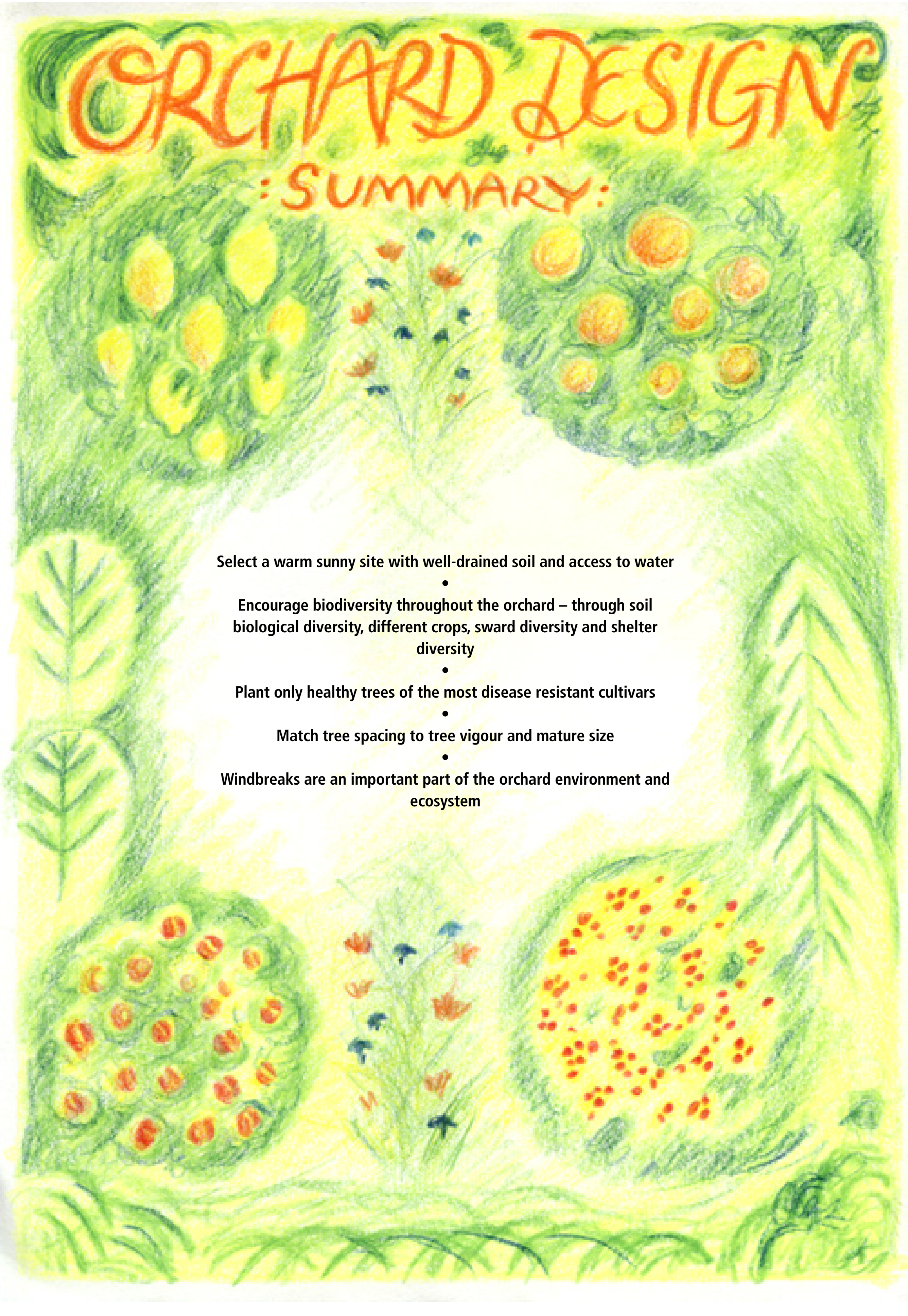
Windbreaks and hedgerows have important roles to play in the organic citrus orchard. They are able to raise average temperatures within the orchard, prevent wind damage to the fruit and trees, add to the biodiversity of the orchard ecosystem, capture and return nutrients to the orchard ecosystem, host and enhance populations of beneficial insects and birds. Windbreak trees may also supply timber and firewood to supplement the orchard's income. The needs of citrus trees for shelter will change as the orchard matures. Young trees need more shelter, but as the trees fill their allotted spaces 'self-sheltering' may replace some of the need for additional shelter. The yields of most horticultural crops can be reduced by exposure to wind. Wind tends to reduce the rate of photosynthesis, which is always closely related to yield and growth. It can also cause crop damage (especially fruit blemish) and increased rates of water loss from the orchard.

However, they need to be carefully placed and be of suitable dimensions to reduce but not prevent airflow, to avoid air turbulence and wind funnelling and not compete unduly with the crop for light, water and nutrients. Where there are adjacent horticultural properties windbreaks should also be compatible on a wider landscape scale. Taller trees should be spaced apart rather than being solid walls, which can increase wind damage to the crop by the creation of turbulence.

Flags kept flying at points around the orchard can be used to monitor wind – as they become tattered with age they give an indication of wind frequency/strength in different parts of the orchard.

Generally taller evergreen trees are placed on the southern boundaries, while smaller sized mixed evergreen and deciduous trees are placed on the other boundaries. Windbreaks should ideally include smaller shrubs and trees as an under-storey. Species known to attract birds and beneficial insects are selected, while species known to host pest and diseases should be avoided. For example, Tasmanian blackwood and conifers can host ladybirds, while bamboo can host sap-sucking pests. It is possible that native plants will increase biodiversity further by supporting endemic plant and animal species. For example, native predators of lemon tree borer are associated with this pest in native bush. Flowering trees and shrubs attract and enhance populations of beneficial insects. A diverse mix of trees and shrubs will encourage many species of birds acting in turn to reduce populations of fruit-eating birds such as silvereye. Most native birds prefer the fruit of native plants to exotic fruits such as citrus, giving a further reason to have native plants in the windbreaks.

Competition with the crop from shelter trees for nutrients and water can be reduced by root pruning, root barriers (e.g., trenches) or by using deep rooting species such as alders.



Select a warm sunny site with well-drained soil and access to water

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Encourage biodiversity throughout the orchard – through soil biological diversity, different crops, sward diversity and shelter diversity

•

Plant only healthy trees of the most disease resistant cultivars

•

Match tree spacing to tree vigour and mature size

•

Windbreaks are an important part of the orchard environment and ecosystem

References

35. Harty, A. (1996). Seedless citrus. *The Orchardist, 69*(10): 42-43.

36. Birmingham, E. (1998). Australian native citrus: wild limes from the rainforest to the desert. *New Crops Newsletter,* [online]. Retrieved 11 February 2003 from the World Wide Web: www.newcrops.uq.edu.au/newslett/ncn10211.htm

37. Mooney, P (ed.). (2001). *Growing citrus in New Zealand.* NZ: HortResearch & NZCGI.

Further information on citrus propagation:

NZ Citrus Budwood Scheme,
Kerikeri Research Centre,
PO Box 23,
Kerikeri.
Phone 09 407 9611

Books:

Mooney, P (ed.). (2001). *Growing citrus in New Zealand.* NZ: HortResearch & NZCGI.

Reuther, W. (ed.). (1973). *The citrus industry vol III: production technology.* Riverside:University of California.

Further information on windbreaks:

Brandenburg, B. (1993). Brandenburg's Concerto. *Growing Today, 7*(6): 28-37.

Bryant, G. (1995). Splashing out on shelter. *Growing Today, 9*(10): 17-23.

Howard, M. (1986). *Wind control: the options*. New Zealand & Southern Hemisphere Horticulture, December 31: 6-7.

Lewis, O. (1999). Totara: waiting for the forester. *NZ Tree Grower, August:* 13-15.

Nicholas, I.D. (1993). *Speciality timber species for farm sites.* Proceedings of NZ Grape & Wine Symposium, 8: 55-73.

Palmer, H., Gardner, B., Hislop, M. & Buttery, N. (2003). Trees for shelter: basic principles revisited. *NZ Tree Grower, 24*(1): 38-40.

Pearce, J. (2002). Blowing in the wind: the impossible dream Part V. *Organic NZ, 61*(1): 24-31.

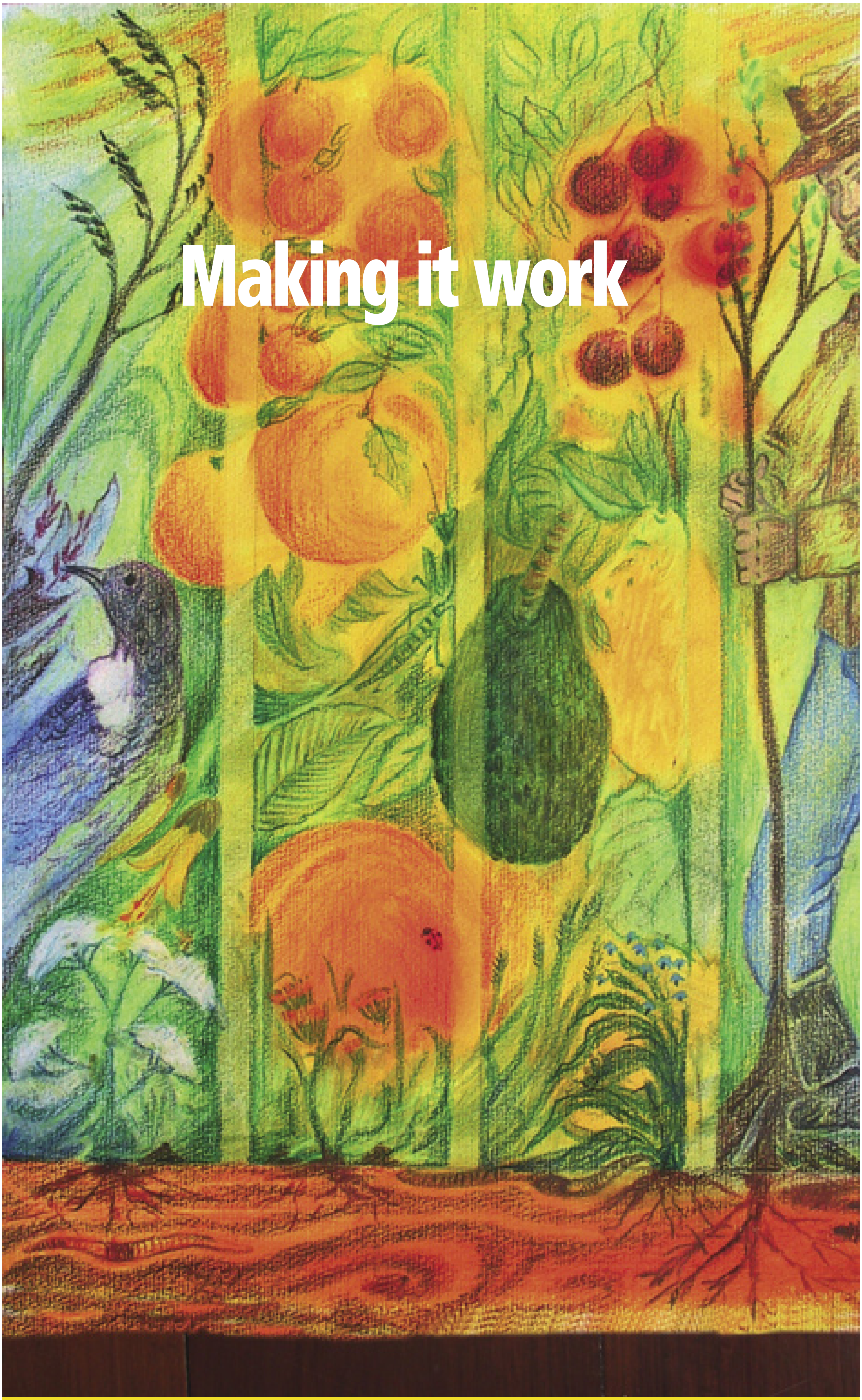
Table 9. **Citrus cultivar information in *The Orchardist***

Title	Author	Issue
Citrus cultivar performance in Northland: oranges, lemons and grapefruit.	Mooney, P. & Anderson, P.	Vol 64(5); June 1991:p31-34
Satsumas: ten cultivars compared.	Richardson, A. et al.	Vol 64(2); March 1991: p22-25
Citrus cultivar performance in Northland: mandarins, tangelos and tangors.	Mooney, P. et al.	Vol 64(4); May 1991: p30-34
New navel orange planting options.	Harty, A.	Vol 75(3); April 2002: p44-45.
Mandarin planting options.	Harty, A.	Vol 66 (5); June 1993: p43-46.
Encore: a mandarin with exciting possibilities.	Sale, P.	Vol 67(1); Feb 1994: 12-13.
Limes		
Yen Ben lemon: an attractive option for citrus growers	Harty, A.	Vol 75(6); July 2002: 58-59
New Zealand citrus budwood scheme: the 2002 update	Currie, A. et al.	Vol 75 (8); Sept 2002: 62-65
Meyer lemons	Sale, P.	Vol 66(5); June 1993: 40-42
Japanese production practices for Satsuma mandarins	Harty, P. & Anderson, P.	Vol 68(3); April 1995: 40-43

Table 10. **Orchardist articles on citrus rootstock and propagation**

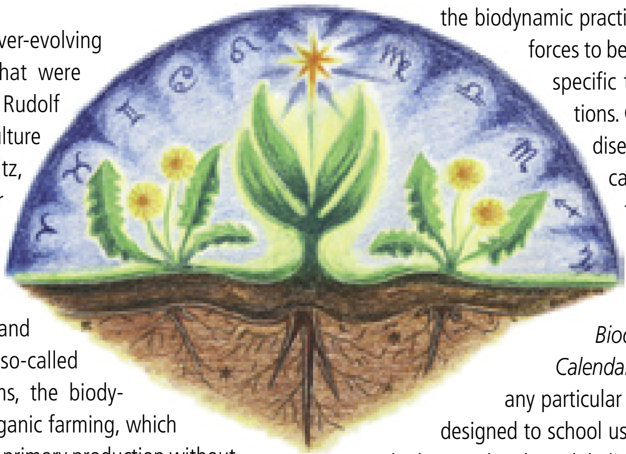
Title	Author	Issue
Satsuma rootstock trial: first results	Harty, A. et al.	Vol 70(8); Sept 1997: p45-47
Eliminating off-type citrus rootstocks	Mooney, P & Harty, A.	Vol 66(7); Aug 1993: 35-37
Beware of off-type citrus rootstocks	Mooney, P & Killen, W.J.	Vol 64(8); Sept 1991: 40-42
How do rootstocks affect canopy development?	Richardson, A. et al.	Vol 67(10); Nov 1994: 41-43
Roots: the vital link	Richardson, A	Vol 67(9); Oct 1994: 46-48
Yen Ben lemon: and attractive option for citrus growers	Harty, A.	Vol 75(6); July 2002: 58-59
New navel planting options	Harty, A.	Vol 75(3); April 2002: 44-45
New citrus rootstocks – an update	Currie, A. et al.	Vol 76(2); March 2003: 44-46

Making it work



Biodynamics

'Biodynamics is a human service to the earth and its creatures, not just a method for increasing production or for providing healthy food'[38].



Biodynamic practice is an ever-evolving system of landuse practices that were originally introduced by Dr Rudolf Steiner, who delivered his Agriculture Course in 1924 in Koberwitz, Silesia (Poland today). Dr Steiner contributed profound insights into a deeper understanding of man, our condition, our civilisation and relevant to this context, the so-called natural world. In general terms, the biodynamic method is one way of organic farming, which integrates human existence into primary production without destroying our habitat.

Based on a foundation of sound practice and good husbandry, biodynamics (please note the 'dynamics' or process orientation) focuses on the whole, the farm as an organism, the bigger picture and seeks positive integration of all constituent parts. Soil fertility is considered of primary importance. Any problems in terms of crop or animal health are more likely addressed by searching for long-term solutions on a causal rather than a symptomatic level. The judicious use of the biodynamic field- and compost-preparations is an essential tool for balancing and guiding processes which ultimately determine good health and sustained production. Man, in this case the grower or farmer, is seen as an integral part of the farm organism and ideally much more than a mere manager of inputs and outputs.

Cosmic and planetary aspects

In contrast to healthy soil, the less visible sphere of planetary aspects is viewed as a necessary counterbalance for healthy growth. These forces influence plant- and animal growth, and the biodynamic practitioner endeavours to harness the forces to best effect. This will naturally lead to specific timing of activities and interventions. Good seed germination, improved disease-resistance, extended shelf life can all be enhanced by balancing the factors that are responsible for growth. There are calendars that list the important planetary aspects and lunar cycles. The *Biodynamic Farming and Gardening Calendar of New Zealand* does not specify any particular activities at set times but is more designed to school users in improved understanding of rhythms and cycles, while listing events and aspects of importance extensively. As with all outdoor growing, the weather and possibly other factors may take precedence over any one particular desirable planetary aspect.

Biodynamic practice aims at balancing the processes of humification and mineralisation and pays particular tribute to the interactions of physical, chemical and biological processes within the soil. This life-supporting environment is seen as being more than a visible material phenomenon and contains a vitality that can be translated into other spheres, including that of human nutrition. Biodynamic practice includes the use of a number of special preparations (Table 11). These are prepared and used according to detailed procedures[39].

Table 11. **The composition, preparation and use of the biodynamic preparations.**

Preparation	Composition	Use
500	Cow dung Horn Manure Preparation	Applied to the land at least twice a year to increase soil fertility (vitality)
501	Ground silica Horn Silica Preparation	Sprayed on crops at least once a year to improve plant structure and to increase disease resistance
502	Yarrow flowers	Compost preparation*
503	Chamomile flowers	Compost preparation
504	Stinging nettle – whole flowering plant	Compost preparation
505	Oak bark shaved outer bark	Compost preparation
506	Dandelion flowers	Compost preparation
507	Valerian flowers	Compost preparation
508	Equisetum herb	Spray for protection against fungal diseases

*Added to compost to guide the fermentation process

The biodynamic preparations are used to guide the natural forces at work in growth and fermentation processes and to balance cosmic and terrestrial forces. Biodynamic growers acknowledge that growth cannot be looked on as a mere physical – chemical phenomenon, but that healthy balanced growth is reliant upon forces that we can work with through biodynamic practice. Biodynamic preparations may be seen as quality- and vitality-enhancing catalysts.

Going organic – the conversion period

Converting a conventional orchard to an organic management system can create a new set of problems for the grower. When synthetic fertilisers and pesticides are withdrawn it may take some years for new equilibriums to establish. Difficulties often encountered during conversion include nutrient deficiencies and pest outbreaks. Organic management demands more of the grower than simply substituting conventional chemicals with organic alternatives. It might be necessary for the grower to learn new skills, such as observational skills. In fact, going organic often demands new attitudes and perspectives both from growers and consumers. For example, the minimal intervention approach to growing often requires a suppression of the immediate urge to intervene and solve a problem in order to allow time for natural processes to take effect. This 'hands off' approach can be difficult for growers accustomed to taking more direct control of the farm environment. Additionally, the stand down and transitional period necessary before full organic certification is gained, means the premium often received for organic produce is not immediately available to the grower. It is this premium that can compensate for the reduction in yield that sometimes occurs after organic conversion.

Generally the greatest difficulty experienced during conversion will be pest and disease outbreaks. It will take several seasons before populations of beneficial insects become established. Increasing the orchard's biodiversity by introducing new sward and hedgerow species and avoiding broad-spectrum insecticides can promote this process.

The soil in a conventional orchard may have a depleted level of organic matter especially in the tree row where herbicides have been used. This, along with a degraded soil structure, reduces the soil's ability to supply the trees with sufficient nutrients and to support the high levels of biological activity necessary for efficient nutrient recycling. Nitrogen in particular can be in short supply. Therefore, during the first years it will be necessary to apply larger amounts of compost and mulch as remedies. Also, more use can be made of the concentrated organic fertilisers, such as fishmeal.

Weeds can also be a problem during the conversion period. As soil biological activity increases, weed seeds may become less virulent[40]. Sometimes weed problems will be due to the need for new weed control strategies such as different mowing equipment and mulch. A changed viewpoint can also reveal that 'villain' weeds are in fact allies and performing a useful function.

Many of the problems associated with conversion to organics can be minimised if the orchard has already adopted IFP-type practices beforehand. For example, spraying to pest thresholds rather than calendar spraying, changing from broad-spectrum insecticides to pest-specific ones and using mulch and mowing rather than herbicides – these practices can be implemented several years before applying for certification.

Organic certification

Organic growers may wish to have their properties certified. Certifying organisations codify the rules for managing an organic property (e.g. input audits, on farm inspection and report, wider environmental impacts, compost quality and diversity levels). Certifiers charge for these services.

Copies of organic production standards are available from certifying organisations which outline the above procedures, practices and materials.

In New Zealand there are three bodies that register organic growers; the Bio Dynamic Farming & Gardening Association own the Demeter trademark, the NZ Biological Producers and Consumers Council Inc. that owns the Bio-Gro Trademark, trading as Bio-Gro New Zealand and thirdly, AgriQuality trading as Certenz (please note that the trading name Certenz is going to be phased out and Agriquality will be used in future). All three are members of the International Federation of Organic Agricultural Movements (IFOAM), which is the governing international body. Bio-Gro and AgriQuality are also accredited by IFOAM, Demeter NZ by Demeter International.

The three certifying bodies lay down a strict set of standards relating to management strategies and farm inputs that must be adhered to if certification of a property under a particular trademark is to occur. The farmer/grower contractually agrees each year to abide by the certifier's written standards. These regulations are based on such factors as the environmental impact caused by the manufacture or use of many herbicides, insecticides and fungicides, the effect on soil fertility by synthetic fertilisers and the fostering of ecosystem diversity on various levels within the farming environment. The organisations charge for inspection services and administration of the standards.

Demeter trademark

The Demeter certification trademark denotes agricultural products produced using the biodynamic agricultural techniques detailed by Rudolf Steiner in a course of lectures given in 1924 to a group of landowners in Germany. The methods have been amplified by practitioners around the globe since that time (including NZ in the late 1920s). The Demeter trademark first appeared in Germany in 1928. Biodynamic farmers look towards the living processes that comprise the farm – soil, water, plants, animals, humans, air and wider influences, such as, sun moon and planets.

Bio-Gro New Zealand

Bio-Gro New Zealand was founded in 1984, as an independent, non-profit Incorporated Society, to promote the interest of organic production in New Zealand. Activities include the setting of organic production standards; inspection and verification of Bio-Gro licences and Licence Applicants; research and education. Bio-Gro New Zealand is funded entirely by membership and inspection fees, licensing levies, donations and grants.

Agriquality

Agriquality New Zealand Organic standards are based on internationally recognised standards, which were developed to allow market access to the USA, EU, Australia, Southeast Asia, UK and Japan. The standards introduction quotes 'this standard has been prepared for the purpose of providing minimum requirements to be complied with to gain certification for the production of, and the labeling and claims for organically produced foods.'

OrganicFarmNZ

In 2002 a small growers certification scheme was launched, which is administered by the Soil and Health Association based on Bio-Gro standards. Small regional groups of growers (pods) meet for mutual inspections. An independent auditor oversees. Strictly for domestic marketing.

Far North Organic Growers & Producers Association

This group was founded in 1989 by a group of growers, home gardeners and customers who were interested in organic methods of growing fruit and vegetables. A certification scheme was worked out, standards established and the scheme was running by 1991. Far North Organic Growers & Producers (FNOG) Association has since become a certifying body under Organic Farm NZ. However the original FNOG certification still operates independently for growers marketing locally where this established logo is recognised. Strictly for domestic marketing.

Information and certification sources

Bio-Gro
P O Box 9693
Marion Square, Wellington
Tel: 04 801 9741 Fax: 04 801 9742
Email: info@bio-gro.co.nz Web: www.bio-gro.co.nz

Bio Dynamic Farming and Gardening Association in NZ Inc.
PO Box 39 045
Wellington Mail Centre
Tel: 04 589 5366 Fax: 04 589 5365
Email: info@biodynamic.org.nz
Web: www.biodynamic.org.nz

AgriQuality Ltd
David Brown
PO Box 307
Pukekohe
Tel: 09 237 1807 Fax: 09 238 3757
Web: www.agriquality.co.nz

OrganicFarmNZ (small growers domestic certification scheme)
Soil and Health Association of NZ Inc
PO Box 36-170
Northtcote
Auckland 9
Tel: 09 419 4536 Fax: 09 419 4556
Email: info@organicnz.pl.net
Web: www.organicnz.org

Far North Organic Growers & Producers Association
PO Box 157, Kaitaia
Web: www.farnorthorganics.org.nz

Citrus IPM

Integrated pest management (IPM) or integrated fruit production (IFP) systems integrate a wide range of management techniques to reduce pesticide residues on fruit and the negative impact of orchard management practices on the environment. Biological and cultural controls are combined with selective 'soft' pesticides. The systems are subject to constant refinement and their introduction is seen as a step-by-step process. IPM has been successfully introduced and widely adopted by apple, kiwifruit, summerfruit and viticultural industries. An IPM programme for citrus is currently being developed in New Zealand with research into pest life cycles and natural biological controls[41]. Results from these research projects are likely to greatly benefit organic growers. If organic growers become members of NZ Citrus Growers Incorporated they will receive the latest developments in the IPM research programme in the quarterly newsletter *Citrus News*. IPM field-days are also held in the major citrus growing districts and are also likely to be worth attending by organic growers.

Contact local NZCGI representatives for further details.

Further information

References

38. Storl, W.D. (1979). *Culture and horticulture: a philosophy of gardening*. Wyoming: Biodynamic Literature.

39. Pearce, N. (1993). *A biodynamic farmer's handbook*. Auckland: A.N.Pearce.

40. Ngouajio, M. & McGiffen, M.E. (2002). Going organic changes weed population dynamics. *HortTechnology, 12*(4): 590-596.

41. Sale, P. (1996). Towards integrated pest management for citrus. *The Orchardist, 69*(6): 18-20.

Further information on NZCGI and the citrus IPM programme

NZ Citrus Growers Incorporated,
PO Box 462
Gisborne.
Email: michelle.nzcgi@xtra.co.nz

Further information on biodynamics:

Books:

Proctor, P. (1997). *Grasp the nettle: making biodynamic farming and gardening work.* Auckland: Random House.

Steiner, R. (1974). *Agriculture.* London: Biodynamic Agricultural Association.

Biodynamic Association Website: www.biodynamic.org.nz

Advisory/consultancy:

All advisory work requests are now referred to the Biodynamic Consultancy Society (c/o B. Gillatt, secretary, Redhill, R.D.1, Dargaville), which is an incorporated collegiate of consultants offering a spectrum of expertise. Depending on the type of operation advice is sought for, a number of consultants may be recommended to the client. The consultant is then chosen by the grower/farmer.

The Biodynamic preparations can be obtained at a cost from the Bio Dynamic Farming and Gardening Association and from Garuda Biodynamics Ltd.

Further information

Books on citrus:

Davis, F.S. & Albrigo, L.G. (1994). *Citrus*. Wallingford: Cab International. Mooney, P (ed.). (2001). *Growing citrus in New Zealand.* NZ: HortResearch & NZCGI.

Recommended reading on organics:

Balfour, E. (1975). *The living soil and the Haughley experiment.* New York: Universe Books.

Fukuoka, M. (1978). *The one-straw revolution: an introduction to natural farming.* Emmaus: Rodale Press. 181p.

Howard, A. (1943). *An agricultural testament.* Oxford: University Press.

Innis, D. (1997). *Intercropping and the scientific basis of traditional agriculture.* London: Intermediate Technology.

King, F.H. (1927). *Farmers of forty centuries.* London: Jonathon Cape Ltd.

Lampkin, N. (1990). *Organic farming*. Ipswich: Farming Press Books.

Senn, T.L. (1987). *Seaweed and plant growth*. Clemson: Senn.

Periodicals – *Organic NZ, Growing Today, Horticulture News, The Orchardist*

Nutritional value of organic foods.

Lundegardh, B. & Martensson, A. (2003). Organically produced plant foods – evidence of health benefits. Acta Agriculturae Scandinavica, Section B, *Soil and Plant Science, 53:* 3-15.

Worthington, V. (2001). Nutritional quality of organic versus conventional fruits, vegetables and grains. *Journal of Alternative and Complementary Medicine, 7*(2): 161-173.

Suppliers of books on organic and biodynamics:

www.ceresbooks.co.nz

www.touchwoodbooks.co.nz

www.organicnz.org

www.biodynamic.org.nz

Web sites of interest:

www.attra.ncat.org National Sustainable Agricultural Information Service

www.sare.org The Sustainable Agriculture Network

www.rodaleinstitute.org The Rodale Institute www.organic-research.com Organic Research.com

www.permaculture.org.au The Permaculture Research Institute Gold, M.V. (1999). Sustainable agriculture: definitions and terms. Special Reference Briefs Series no. SRB 99 – 02 .

www.nalusda.gov/afsic/AFSIC_pubs/srb9902.htm#term1

Bio-Gro registered products

organicpathways.co.nz

www.rd2.co.nz/pages/bio-gro_reg.html

Garuda Biodynamic Ltd, Te Puke

Further information on marketing:

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