Australian Government

Rural Industries Research and Development Corporation

Alternatives to Copper for Disease Control in the Australian Organic Industry

A report for the Rural Industries Research and Development Corporation

by Melissa Van Zwieten[1], Gordon Stovold[2], Lukas Van Zwieten[1*]

[1]Environmental Centre of Excellence, NSW Agriculture, Wollongbar.
[2]Centre for Tropical Horticulture, NSW Agriculture, Alstonville.
*Corresponding author

July 2007

RIRDC Publication No 07/110
RIRDC Project No DAN-208A

ISBN 1 74151 507 6
ISSN 1440-6845
Literature Review and Inventory of Alternatives to Copper: for Disease Control in the Australian Organic Industry
Publication No. 07/110
Project No DAN-208A

Researcher Contact Details
Dr Lukas Van Zwieten
Environmental Centre of Excellence
NSW Agriculture, 1243 Bruxner Highway
Wollongbar NSW 2477

Phone: 02 6626 1126
Fax: 02 6628 3264
email: lukas.van.zwieten@agric.nsw.gov.au
Website: http://www.agric.nsw.gov.au

In submitting this report, the researcher has agreed to RIRDC publishing this material in its edited form.

RIRDC Contact Details
Rural Industries Research and Development Corporation
Level 2, 15 National Circuit
BARTON ACT 2600
PO Box 4776
KINGSTON ACT 2604

Phone: 02 6271 4100
Fax: 02 6271 4199
Email: rirdc@rirdc.gov.au.
Web: http://www.rirdc.gov.au

Published to Web in July 2007

Foreword

There is a worldwide demand for a reduction in chemical use in agriculture and therefore a need to find economic, social and environmental alternatives. Organic certification agencies have acknowledged this by placing restrictions on the use of copper fungicides. Copper residues in soil resulting from these fungicides impact adversely on soil biology and fertility.

The consequences of reduced availability of copper based fungicides in organic horticulture could devastate the Industry. Therefore there is a requirement to provide alternative disease control measures to ensure the viability of organic horticulture in Australia. A literature review of alternative products and disease control strategies has been undertaken and an inventory of products and technologies available in Australia has been provided.

This project was co-funded from RIRDC Core Funds which are provided by the Australian Government, and NSW Agriculture.

This report, an addition to RIRDC's diverse range of over 1600 research publications, forms part of our Organic Produce R&D program, which aims to facilitate the development of a viable organic industry through increasing adoption of sustainable organic farming systems.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- downloads at www.rirdc.gov.au/fullreports/index.html
- purchases at www.rirdc.gov.au/eshop

Peter O'Brien
Managing Director
Rural Industries Research and Development Corporation

Acknowledgements

The authors thank RIRDC for co-funding this literature review (DAN-208 A). Wollongbar Librarians Jennifer Kirton and Lynne Watt are thanked for providing valuable support in gaining literature used within this report. Robyn Neeson, Justine Cox, Karen O'Malley and Dr Percy Wong from NSW Agriculture are also thanked for supplying information and resources used in this report. The individuals and Companies who responded to our Call for Expressions of Interest are duly acknowledged. We recognise that it was difficult to provide information without compromising IP and sale of products or technologies. The authors would also like to acknowledge the various media outlets and Organisations for publishing/distributing the Expression of Interest. Gary Fan and Jeff Rabbidge from the Australian Government Department of the Environment and Heritage, Chemical Assessment Section, are thanked for their advice and information on registration of products.

Finally, the authors would like to thank Denise Millar and the Organic Subprogram of RIRDC for supporting the project.

Executive Summary

What the report is about
Historically, copper has played a significant role in organic and conventional systems for combating some fungal diseases. More recently however, organic standards have limited the use of copper for disease control, and it is clear that alternative products and technologies are required to maintain productivity and profitability of the Industry.

Who is the report targeted at?
Organic farmers who would benefit from scientific evidence of the efficacy of various 'alternative' products for pest and disease control. As well as manufacturers to encourage research into relevant technologies.

Background
Organic farmers often make use of 'alternative' products for pest and disease control. Their decision to use these products is frequently based on anecdotal (as opposed to scientific) evidence, as to their efficacy. These alternative products are usually unregistered, or sold without sound data. The key limitation of alternative products is that their efficacy of disease control, especially when compared to registered chemical fungicides, is often lower. Thus commercialisation and registration of these alternate products in conventional horticulture is not undertaken. In addition, manufacturers of these products may view the organic market as not large or profitable enough to warrant the expenses associated with bringing these products to the industry.

Aims/Objectives
This project has investigated the availability and efficacy of organically acceptable alternatives to copper based disease control products both internationally and within Australia. The report provides:

- A comprehensive review of data and literature available on alternatives;
- A review of potential efficacy of these alternative products, and their possible use in the Australian organic industry, and
- Recommendations for making these products more available to organic farmers in Australia.

Methods used
The project involved a "National Call for Expressions of Interest" to provide information on products available in Australia. Twenty seven Companies or Individuals responded and were interviewed regarding the use of their products. From the interviews it became clear that many products and technologies are not being pursued to commercial availability. Reasons for this included the strict registration requirements in Australia, and the limited market for these products. In addition, over 400 scientific publications were obtained that were relevant to the report, with in excess of 300 being referenced.

Results/Key findings
The report ranks alternate disease control technologies according to the number of refereed publications and confidence/significance of the data presented. Three categories for ranking technologies were chosen: 1) Technology highly relevant; 2) Technology shows promise; 3) Not enough information currently available.

Those technologies considered **highly relevant** for disease control include:

- Selected biological control agents
- Compost
- Inoculated compost
- Surfactants and biosurfactants
- Antifungal compounds

Those technologies that **show promise:**

- Compost tea
- pH modifiers and bicarbonates
- Foliar calcium and silicone
- Milk products and other organic amendments (eg. molasses)
- Essential oils (eg. tea tree)
- Polymer coatings

Those technologies where **not enough information is currently available**

- Vermiculture products
- Plant extracts excluding essential oils (eg. rhubarb)
- Seaweed extracts
- Colloidal silver
- Potassium permanganate
- Vinegar
- Household antiseptics

In addition to these products that have been reviewed, other technologies including induced and genetic resistance, cultural control and IPM are seen as highly relevant to reducing disease in organic horticulture. These are discussed in the report.

Implications for relevant stakeholders

This report highlights technologies into which there has been insufficient research conducted. The results are relevant for scientists performing research in the organics industry.

Recommendations

Very little scientific evaluation of alternative products is being undertaken in Australia, even though a range of products and technologies claim to reduce plant diseases. The authors of this report strongly urge better scientific evaluation of promising products, and suggest the Organic Industry should investigate pathways for bringing these products to commercial availability. This is likely to include the requirement for licensing of the product through Australian Pesticides and Veterinary Medicines Authority (APVMA), part of the National Registration authority (NRA).

Table of Contents

List of Tables

1. Introduction

The use of chemical biocides to control microbial, fungal and insect plant pests has long been a feature of conventional agricultural practice and their use has made it possible to increase crop yields and food production (Lee 1985). However, many of these biocides have toxic effects that are not confined to their target species, and their application can impact upon organisms that benefit the wider agroecosystem (ie. beneficial organisms).

1.1 Importance of this review for Australian Organic Producers

There is a worldwide demand for a reduction in chemical use in agriculture and therefore a need to find economic, social and environmental alternatives. Organic certification agencies have recognised this and have begun restricting the use of copper (IFOAM -International, Soil Association UK, BFA and NASAA, Australia).

This project has direct relevance to all organic horticulturalists, as copper is the primary chemical currently used for disease control. An essential aspect of reducing the toxicity of copper in soil is the reduction or elimination of further inputs of this chemical.

The restrictions in copper application in Australian organic agriculture necessitate the scientific evaluation and registration (where required) of suitable alternatives, a process that will take several years.

The consequences of no alternatives to copper could be devastating to the Industry. Benefits of a scientific evaluation of copper alternatives will initially be recognised in organic horticulture, but will flow to conventional agriculture as cost-effective and environmentally sound alternatives to synthetic chemicals are evaluated and eventually registered.

Commercially available products that increase soil organisms and protect from pathogens have been marketed to the organic industry. Most of these soil additives have not undergone independent, rigorous scientific evaluation and therefore may not be effective as claimed. On the other hand, these alternatives may have disease control properties not yet recognised.
This literature review and product inventory will be extremely beneficial to the Australian Organics Industry, as it will provide an independent evaluation of products and will review knowledge to date on these products.

1.2 Fungicide history and copper usage

Naturally occurring compounds such as sulphur, mercury and copper are recognised as the first fungicides (Croplife 2002). Recordings from 1000BC implicate sulphur as being the oldest effective fungicide whereby it was used as a soil fumigant (Ware 1978; Croplife 2002). Copper sulphate was used as a cereal seed treatment in 1761 (Copper Development Association 2003). However, it was not until the 1880s that copper sulphate fungicides rapidly developed due to the ‘accidental’ discovery of the Bordeaux mixture. At this time, farmers in the Bordeaux region, France were applying a paste mixture of copper sulphate and lime to grapes that were bordering the highways to deter passer-by’s. The French scientist, Millardet observed these grapes were also free of downy mildew (Floyd 1991; Copper Development Association 2003). By 1885, Millardet had completed experiments which confirmed this mixture controlled the mildew disease at a considerably low cost of 50 Francs (equivalent to approximately AUS$12.25 or 7.62 Euro) per hectare of vines (10,000 plants; includes materials and labour) (Schneiderhan 1933). The Bordeaux mixture was the first fungicide to be used on a large scale world-wide (Schneiderhan 1933).

Around this same period, a number of other plant diseases were greatly impacting on crop yields around the world. The impacts from these crop losses generated further attention towards science and the development of fungicides. For example, 1845 to 1851 marks the potato famine in Ireland which was caused by the fungus *Phytophthora infestans* (late blight). This famine resulted in a death of approximately 1 million people and the massive migration of Irish people to America (Ware 1978). The scientific community at the time had little understanding of the relationship between plants (hosts) and pathogens (Peterson *et al.* 1995). Thus, the finding of the highly effective copper fungicides was welcomed and sparked the development and discoveries of a range of fungicides (Peterson *et al.* 1995). Table 1 indicates the range of copper-based fungicides which have been developed. Copper-based fungicides have been used to effectively control a wide range of plant pathogens on a variety of crops (Table 2).

Table 1: Inorganic copper compounds used as fungicides in Australia

Name	Chemical formula	Uses
Cupric sulfate	$CuSO_4.5H_2O$	Seed treatment and preparation of Bordeaux mixture
Copper dihydrazine sulfate	$CuSO_4(N_2H_5)_2SO_4$	Powdery mildew Black spot of roses
Copper oxychloride	$3Cu(OH)_2.CuCl_2$	Powdery mildews
Copper oxychloride sulfate	$3Cu(OH)_2.CuCl_2$ and $3Cu(OH)_2.CuSO_4$	Many fungal diseases
Copper zinc chromates	$15CuO\text{-}10ZnO.6CrO_3.25H_2O$	Diseases of potato, tomato, cucurbits, peanuts and citrus
Cuprous oxide	Cu_2O	Powdery mildews
Basic copper sulfate	$CuSO_4.Cu(OH)_2.H_2O$	Seed treatment and preparation of Bordeaux mixture
Cupric carbonate	$Cu(OH)_2.CuCO_3$	Many fungal diseases
Copper hydroxide	CuH_2O_2	Many fungal diseases

(source: Ware 1978)

Agriculture has developed a wide range of organic and inorganic fungicides (Appendix 2) (Ware 1978). Protectant fungicides (e.g. dithiocarbamates) act at the site of application by contact with the fungus whereby they affect a number of metabolic pathways and have a broad spectrum of activity and thus resistance issues are generally limited (Letham and Stovold 1995). Conversely, specific fungicides (e.g. benzimidazoles) kill fungi through specific modes of action, many are able to move systemically through plants without harm but have a limited spectrum of activity and consequentially, resistance issues are more common. Additionally, a better understanding of pathogen-host lifecycles has resulted in changes in cultural methods (e.g. monitoring and timing of applications) resulting in an overall decrease of fungicide volumes required to control disease (Ware 1978).

Table 2: Plant pathogens controlled by copper-based fungicides

Disease	Pathogen	Crop	Reference
Alternaria blight	*Alternaria solani*	Tomato	(Copper Development Association 1948; Mabbett and Phelps)
Alternaria blight	*Alternaria solani*	Potato	(Singh *et al.* 1997)
Alternaria blight	*Alternaria. brassicae*	Radish	(Hussaini and Singh 1989)
Anthracnose	*Colletotrichum gloeosporioides Dothiorella aromatica*	Avocado	(Peterson and Inch 1980; Labuschagne and Rowell 1983; Darvas 1983b)
Anthracnose	*Colletotrichum gloeosporioides*	Custard apple	(Gaikwad *et al.* 2002)
Anthracnose	*Colletotrichum gloeosporioides* var. *minor*	Macadamia	(Fitzell 1994)
Anthracnose	*Colletotrichum gloeosporioides*	Mango	(Sanders *et al.* 2000)
Bacterial canker	*Pseudomonas mors-prunorum*	Plum	(Copper Development Association 1948)
Bacterial spot	*Xanthomonas campestris* pv. *mangiferae-indicae*	Mango	(de Wet 1982)
Black pod disease	*Phytophthora palmivora*	Cocoa	(Jollands *et al.* 1989; Reddy and Mohan 1984)
Black Spot	*Pseudocercospora purpurea*	Avocado	(Darvas 1982; Darvas 1983a; Korsten *et al.* 1994)
Canker	*Pestalotiopsis psidii* and *Glomerella psidii*	Guava	(Rawal and Ullasa 1988)
Canker (trunk) and Root Rot	*Phytophthora cinnamomi*	Macadamia	(Fitzell 1994; 1990)
Citrus canker	*Xanthomonas campestris* pv. *citri*	Citrus	(Timmer 1988)
Downy mildew	*Peronospora parasitica*	Cabbage	(Copper Development Association 1948)
Downy mildew	*Plasmopara viticola*	Grapevine	(Lameri *et al.* 2002)
Downy mildew	*Peronospora destructor*	Onion	(Copper Development Association 1948; Develash and Sugha 1997)

Disease	Pathogen	Crop	Reference
Fruit rot	*Cladosporium oxysporum*	Strawberry	(Shitole *et al.* 2000)
Ganoderma wilt disease	*Ganoderma lucidum* and *G. applanatum*	Coconut	(Nambiar *et al.* 1992)
Grey mould	*Botrytis* spp.	Cut flowers	(Copper Development Association 1948)
Grey mould	*Botrytis cinerea*	Geranium	(Moorman and Lease 1992)
Grey mould	*Botrytis cinerea*	Grapevine	(Gullino *et al.* 1984; Gullino and Morando 1984)
Grey mould	*Botrytis cinerea*	Hazelnuts	(Beradze and Dzimistarishvili 1985)
Heart rot	*Phytophthora [nicotianae] var. parasitica*	Pineapple	(Prakasam and Subbaraja 1994)
Husk spot	*Pseudocercospora macadamiae*	Macadamia	(Fitzell 1994; Lonsdale JH 1991)
Late Blight	*Phytophthora infestans*	Potato	(Copper Development Association 1948)
Leaf mould	*Cladosporium fulvum*	Tomato	(Copper Development Association 1948; Thakur and Singh 1983)
Leaf spot	*Cercospora beticola*	Beetroot	(Copper Development Association 1948)
Leaf spot	*Septoria apii-graveolentis* and *S. apii*	Celery	(Copper Development Association 1948)
Leaf spot	*Pseudomonas burgeri*	Cucumber	(Marinescu 1980)
Leaf spot	*Xanthomonas campestris* pv. *vitians*	Lettuce	(Carisse *et al.* 2000)
Leaf spot	*Mycosphaerella fragariae*	Strawberry	(Copper Development Association 1948)
Peach leaf curl	*Taphrina deformans*	Peach and Nectarine	(Copper Development Association 1948; Tate and Van der Mespel 1985; McCain 1983)
Pink limb blight	*Corticium salmonicolor*	Macadamia	(Fitzell 1994)
Postharvest diseases	*Botryodiplodia theobromae, Colletotrichum*	Avocado	(Darvas *et al.* 1987)

Disease	Pathogen	Crop	Reference
	gloeosporioides, Dothiorella aromatica, Fusarium decemcellulare, Pestalotiopsis versicolor, Phomopsis perseae and *Thyronectria pseudotrichia*		
Potato soft rot	*Erwinia carotovora* subsp. *carotovora*	Potato	(Zhang *et al.* 1993)
Powdery mildew	*Peronospora* sp.	Grape	Millardet (1885) in (Schneiderhan 1933)
Powdery mildew	*Oidium* sp.	Mango	(McMillan 1973)
Powdery mildew	*Sphaerotheca aphanis*	Strawberry	(Viret *et al.* 1998)
Root Rot	*Solanum melongena*	Eggplant	(Datar *et al.* 1992)
Rust	*Puccinia psidii*	Guava	(Ruiz *et al.* 1991)
Algae leafspot	*Cephaleuros virescens*	Litchi	(Gupta 1992)
Scab	*Venturia inaequalis*	Apple	(Copper Development Association 1948)
Sigatoka disease	*Cercospora musae*	Banana	(Huq *et al.* 1994)
Sooty blotch	*Akaropeltopsis* sp.	Avocado	(Kotze *et al.* 1981; Kotze *et al.* 1982)

In many instances, pathogens have mutated over time and become resistant to many of the fungicides. Copper based fungicides have multi-site activity, therefore, there is a lower risk of pathogens developing resistance to this group. Other multi-site fungicides that can be included in this group include Captan® and Thiram®. Searches of the literature failed to discover reported resistance to multi-site fungicides in Australia. There is some overseas data that indicates tolerant strains may appear. Two bacterial species have developed resistance to copper-based bactericides, namely Pseudomonas syringae (Wilson et al. 1998; Vanneste et al. 2003) and Xanthomonas campestris pv. vitians (Wilson et al. 1998; Carisse et al. 2000). In addition, there is some indication in the literature that Cephalosporium sacchari is able to produce extracellular detoxifying substance(s) which effectively provides this fungus with a tolerance level of 7 times the toxic dose of copper sulfate (Reddi et al. 1987). While Botrytis cinerea has been controlled by copper-based fungicides on hazelnuts (Beradze and Dzimistarishvili 1985), grapevine (Gullino and Morando 1984) and geraniums (Moorman and Lease 1992), copper hydroxide has been ineffective on grey mould of strawberries (Washington et al. 1992). Thus, fungal pathogen resistance cannot be ruled out as a potential threat to this class of fungicide.

In Australia, copper-containing sprays of various formulations (Table 1) have been used to control fungal diseases in pome and stone fruit orchards, vineyards and vegetable crops for well over 100 years (Merry et al. 1983).

In Australasia over 7500 t yr-1 of Cu fungicides are used, representing 13% of the global total (Lepp et al. 1994). In stark comparison, England and Wales were estimated to use only 8 t of Cu fungicide between them in the year 2000 (Nicholson et al. 2003). Prolonged use in Europe has lead to high levels in the soil (200-500 mg/kg in France, Brun et al. 1998), which has affected a large portion of agricultural land.

An example of an industry reliant upon copper fungicides in Australia is the avocado industry. Avocado orchards on the north coast of New South Wales have had copper oxychloride, cuprous oxide, copper hydroxide and copper ammonium acetate applied at up to 15 times per year mainly against anthracnose (Colletotrichum gloeosporoides) at recommended foliar application rates of 3-6 kg ha-1 (Van Zwieten et al.in press). By contrast the use of copper-containing products in organic farming practices in Australia is restricted: Copper sulphate and hydrated lime mixtures, copper hydroxide and copper sulphates are permitted by certifying authorities but copper oxychloride is prohibited (Biological Famers of Australia 2003). Further, since 2002, the International Federation of Organic Agriculture Movements (IFOAM) has regulated total copper input on organic farms to a maximum of 8 kg ha-1 yr-1. These restrictions applied by the organic farming industry acknowledge the potential for copper levels in orchard top-soils to accumulate with repeated application.

Horticultural and viticultural operations with a long history of copper fungicide application have resulted in accumulations of copper in surface horizons (Gallagher et al. 2001; Chaignon et al. 2003). Similarly, avocado orchard soils in northern NSW were shown to have residues of copper ranging between 280-340 mg/kg (Merrington et al. 2002).

1.3 Impacts of copper on non-target species

Copper is an essential element and required by all organisms, indeed deficiency results in reduction in biological function and potentially death. However, elevated concentrations of copper are toxic and when found in soils may result in a range of effects including reduced biological activity and subsequent loss of fertility (Dumestre et al. 1999).

Copper residues in avocado orchards have recently been shown to impact significantly on soil microorganisms (Merrington et al. 2002). Available copper residues resulted in reduced microbial biomass, significantly increased respiration and metabolic quotient, indicating the microorganisms are stressed. Elevated Cu concentrations have been shown to reduce beneficial mycorrhizal associations (Graham et al. 1986; Kong 1995; Liao et al. 2003) reduce microbial activity and function (Bogomolov et al. 1996) and impact a range of mesofauna (Böckl et al. 1998).

Thrupp (1991) found that copper arising primarily through application of Bordeaux tended to be associated with areas of high organic matter content in former banana plantations in Costa Rica. These soils were damaging to subsequent crops (i.e. phytotoxic). In the Thrupp (1991) study, residues ranging between 20 and 4000 mg kg-1 were shown to have had a significant adverse effect on once fertile productive agricultural soils. It is likely that copper residues were toxic to soil organisms, restricting bioturbation of soil, hence resulting in accumulation of organic materials. Furthermore, (Alva et al. 2000) observed that at low soil pH, copper was bound to the organic fraction, however, as pH increased phytotoxicity developed.

Soils that contain significant copper residues have been observed to have few earthworms (Van Rhee 1967), reduced surface activity (fewer castings visible at the soil surface) and greater litter build-up (Ma 1984). At sites in a study on avocado orchards in northern NSW (Merrington et al. 2002) an absence of earthworms in areas of copper contamination was accompanied by a thick layer of organic matter (ca. 10-30 cm deep) that was clearly stratified on the soil surface, with little evidence of breakdown and incorporation into the sub-surface layers.

A strong correlation has been observed between soil-copper concentration and the level of copper in earthworm tissues (Ma et al. 1983; Morgan and Morgan 1988; Beyer et al. 1982). It has been noted that earthworms exhibit sublethal toxic responses at relatively low concentrations of copper (9-16 mg kg-1) (Helling et al. 2000; Kula et al. 1997). The enchytraeid worm Cognettia sphagnetorum was shown to actively avoid copper contaminated soil (Salminen and Haimi 2001). Copper oxychloride has recently been shown to reduce populations of the earthworm Aporrectodea caliginosa in field trials six months following application of the fungicide (Maboeta et al. 2003).

Other non-target species include mites (Michaud and Grant 2003), entomopathic fungus (McCoy et al. 1996) and nematodes (Jaworska and Gorczyca 2002). In some instances, these species have been stimulated by copper applications and have resulted in major outbreaks of a pest and subsequent losses in production. Thus, the environmental side effects of copper-based fungicides may be more wide spread than the impacts on soil health and soil biota. Further investigations are required to substantiate these effects.

1.4 Impacts of copper on soil health

Organic horticulturalists understand the importance of a healthy fertile soil to provide adequate nutrients, water, support and also protection from pests and diseases. A diverse, abundant soil fauna (including bacteria, fungi, mites, earthworms) has been shown to out compete and exclude pathogenic organisms in numerous international studies.

Earthworms have been suggested as useful indicators of soil health (de Bruyn 1997; Paoletti et al. 1998). Through their feeding and burrowing activity, earthworms aid in decomposition and incorporation of organic matter, increase the number of water soluble aggregates, improve water infiltration, aeration, drainage and root penetration, and increase microbial activity (Lee 1985). Earthworm casts and burrow walls exhibit higher concentrations of total and plant-available elements than surrounding soil and it has been recognised that surface feeding species horizontally and vertically disseminate micro-organisms, spores, pollen and seeds (Makeschin 1997) and can reduce plant pathogens through digestion of fungal spores (Hirst et al. 1995).

Therefore practices that reduce earthworm populations in soil can lead to a reduction in soil health, hence exasperating disease or nutrient availability issues in soil.

A recent study in SE QLD assessed the effects of copper fungicide on anthracnose on avocados. The study showed the use of copper significantly reduced the numbers of bacteria, filamentous fungi and yeasts on leaf and fruit surfaces. Furthermore, there was a significantly higher disease occurrence on the copper-sprayed fruit (Stirling et al. 1999). The authors attributed this to the ability of the naturally occurring microorganisms to suppress pathogenic species.

1.5 Additional concerns of copper use

Copper spray residues have the potential to adversely impact on quality parameters such as appearance or taste. For instance, visible blue copper spray residues have resulted in the rejection of export avocado fruit (Korsten et al. 1993). Losses from visual quality controls are expensive and unsustainable for growers. In terms of taste, Millardet (1885) questioned whether copper residues would impact on the flavour of wine. However, research investigating the impacts of copper and taste (on any crop) were not located during the literature review. These additional concerns, while relatively minor in comparison to soil health issues and restrictions imposed by the organics industry, as evidenced by the lack of published research, may also provide incentives for alternative products to be examined.

2. Literature review for alternatives to copper-based fungicides

Over 400 scientific publications were utilised to develop this literature review on alternatives to copper for disease control in organic horticulture. Following the chemical revolution of the early 20th Century, research into alternative control measures for plant diseases came back into favour in the late 1960s and early 1970s and has continued to grow due to increasing interest in the environment and shift away from traditional pest control utilising chemicals (Cook and Baker 1996). This is evidenced by the increasing number of papers found in the literature from this period in regard to biological controls, genetic resistance, induced resistance, integrated pest management (IPM), nutrition, mulches, composts (including compost teas), surfactants, biosurfactants and natural products (e.g. milk, molasses and essential oils).

2.1 Methodology for literature review

A general review of available international scientific literature (reports, papers and books) was undertaken to determine a broad range of alternatives to copper-based fungicides. Databases searched included WebSpirs, Science Direct and Current Contents. A general search of internet resources (e.g. Google search engine) was also conducted to gather non-scientific data and reports in regard to alternative products. A Procite Database was constructed for the storage of literature review results, which is available with this report.

A National Call for Expressions of Interest for the provision of information relating to alternative products to copper-based fungicides, for use in the organics industry, was released (Appendix 1). This Expression of Interest (or summary) has been published in numerous newspapers (e.g. Acres, Agriculture Today, The Land), industry journals (e.g. The Grower, Australian Organic Journal), newsletters (e.g. Organic Update, Organic Federation of Australia, Canberra Organic Growers, Organic Herb Growers) and posted on many industry web sites (e.g. Biological Farmers of Australia, The Land, ABC, Plan Organic (Irish organisation)). Information regarding the project was also disseminated via radio interviews in both NSW (e.g. ABC, Lismore; 2GM, Goulburn) and Queensland (e.g. ABC, Toowoomba). The media release was also distributed to all State Agricultural Departments for internal distribution.

Individuals and Companies provided information in regard to alternative products and disease control strategies currently in use in Australia (Table 5). A number of commercial-in-confidence products have been identified and legal processes were undertaken to ensure the protection of these products and the release of information for this project. Phone interviews with relevant stakeholders were conducted to obtain detailed information on alternative products.

2.2 Hierarchy of disease control

The choice of a treatment control strategy should follow select criteria. Many of the alternative products can satisfy most of the following criteria:

- Least disruptive of natural controls;
- Least hazardous to human health;
- Least toxic to non-target organisms;
- Least damaging to the general environment;
- Most likely to produce a permanent reduction of the pest population;
- Easiest to carry out effectively; and,
- Most cost-effective over the short and long terms.

(Source: Olkowski *et al.* 1991)

2.3 Environmental and human health concerns of alternative products

Microorganisms have been knowingly used to control plant diseases for over 100 years (Winding *et al.* 2004). However, risks of using biological control agents are often forgotten. While the microbes selected may naturally occur in the environment, there are concerns that altering the proportion of these microbes will result in environmental impacts on non-target species including mycorrhizal and saprophytic fungi, soil bacteria, plants, insects, aquatic and terrestrial animals and humans (Brimner and Boland 2003). The authors argue dry spored bio-control agents could potentially become a problem (e.g. allergen to humans) as these spores are more suited to air transport than wet-based spores and therefore more likely to be spread widely. The difference between wet-spore and dry-spore agents has been highlighted under the section Biocontrol Agents.

Recently, there has been evidence that significant non-target effects may occur with bacterial biocontrol agents (Winding et al 2004), however effects were generally observed as short term and they did not impact on soil health.

Potential impacts of biological control agents on human and environmental health are discussed in the registration requirements for the National Registration Authority of Australia (http://www.apvma.gov.au/guidelines/bioagprod.shtml). This has highlighted the need for suitable evaluation of products, and is discussed in a separate section of this report.

The growth and survival of serious human pathogens including *E. coli* O157:H7 and *Salmonella* in compost tea has recently been discussed (Duffy *et al*., 2004). The authors from Washington State University questioned the notion that human pathogens cannot survive in compost tea, and demonstrated that in fact brewed teas where molasses levels were greater than 0.2% could lead to human pathogen growth. It was shown that the growth of the human pathogens only required a very small inoculum level (levels that are generally not detectable) in the compost. The source of the inoculum included both dairy and chicken manures used in compost production.

2.4 Biological controls

Biological control measures include the use of cats to control rodents which can be dated back to ancient Egypt through to the impressive control of Prickly Pear (*Opuntia stricta*) by the *Cactoblastis* moth larvae in Australia in 1925 where an estimated 4 million hectares of farming land was relieved of prickly pear infestation within 10 years. While these macro-organisms are readily observed to be effectively controlled by other macro-organisms (by competition, parasitism and other modes of action) recent research has investigated the use of using micro-organisms to provide efficient, effective and inexpensive control measures for a range of pests and diseases. For example, the *Bacillus thuringiensis* (Bt) toxin has been used for the control of insects in the Australian cotton industry since the mid 1980's while the genetically modified BT cotton was available since the mid 1990's. In plant pathology research it is not surprising that a number of micro-organisms have also been identified as potential control agents for disease-causing pathogens by enhancing conditions to allow biocontrol agents to provide disease control using similar modes of actions (e.g. competition and parasitism).

A range of potential biocontrol agents have been identified around the world to be used on a variety of crops and pathogens (Table 3). Possibly the two most studied microbial bio-control agents, as indicated by a large number of research papers and their incorporation into commercial products, are *Trichoderma* and *Bacillus*.

Table 3: Biological control agents and the pathogens they control

Biological Control Agent	Pathogen/disease controlled	Crop	Reference
Agrobacterium radiobacter (e.g. strain K84)[1]	*Agrobacterium tumefaciens* (Crown Gall)	Peach (and other crops)	(Htay and Kerr 1974)
Ampelomyces quisqualis[1]	*Uncinula necator* (Powdery mildew)	Grape	(Falk *et al.* 1995a; Falk *et al.* 1995b)
Arthrobotrys dactyloides[2]	*Meloidogyne spp* (root knot nematodes)	Tomato	(Persson and Jansson 1999)
Arthrobotrys dactyloides[2]	Nematodes	Barley	(Bordallo *et al.* 2002)
Ascocoryne sarcoides[1]	Various decay organisms	Black spruce	(Basham 1973)
Bacillus licheniformis[1]	*Colletotrichum gloeosporioides* (anthracnose), *Nattrassia mangiferae* (stem end rot)	Mango	(Korsten *et al.* 1993; de Villiers and Korsten 1996)
Bacillus subtilis[1]	*Penicillium digitatum* and *P. italicum* (green and blue moulds)	Citrus	(Obagwu and Korsten 2003)
Bacillus subtilis[1]	*Botrytis cinerea* (stem canker)	Tomato	(Utkhede and Mathur 2002)
Bdellovibro[1]			
Chaetomium globosum[1]	*Diplocarpon rosae* (black spot)	Rose	(Prasad *et al.* 2002b)
Cladosporium oxysporum[2]	*Botrytis cinerea* (petal blight)	Rose	(da Tatagiba *et al.* 1998)
Cladosporium cladosporioides[2]	*Botrytis cinerea*	Tomato	(Eden *et al.* 1996)
Coniothyrium minitans[1]	*Sclerotinia sclerotiorum* (dampening off)	Celery and lettuce	(de Vrije *et al.* 2001; Jones and Whipps 2002)
Dactylella leptospora[2]	Nematodes		(Timm *et al.* 2001)
Cryphonectria (Endothia) parasitica[1] (hypovirulent strain)	*Cryphonectria (Endothia) parasitica* (Chestnut blight)	Chestnut	(Fahima *et al.* 1994)
Erwinia amylovora[1] (*hrp* mutant)	*Erwinia amylovora* (fire blight)	Apple	(Faize *et al.* 1999)
Fusarium oxysporum[1] (hypovirulent strain)	*Fusarium oxysporum* (fusarium wilt)	Soybean	(Kilic and Griffin 1998)
Gliocladium virens[1]	*Sclerotium rolfsii*	Tomato and capsicum	(Mao *et al.* 1998)

Biological Control Agent	Pathogen/disease controlled	Crop	Reference
Gliocladium roseum[1]	*Botrytis cinerea*	Raspberry	(Yu and Sutton 1997)
Hansfordia pulvinata[2]	*Fulvia fulva*	Tomato	(Tirilly 1991)
Laetisaria arvalis[1]	*Rhizoctonia solani* (aerial blight and root rot)	Rosemary	(Conway *et al.* 1997)
Myrothecium verrucaria[1]	*Sclerotium rolfsii*	Peanut	(Patil *et al.* 2001)
Nematophthora spp.[1]	Nematodes		(Siddiqui and Mahmood 1996)
Penicillium oxalicum[2]	*Fusarium oxysporum* f.sp. *lycopersici* (Fusarium wilt) and *Verticillium dahliae* (Verticillium wilt)	Tomato	(Larena *et al.* 2003)
Phlebiopsis (Peniophora) gigantea[2]	*Heterobasidion annosum* (Fomes root and butt rot)	Forestry	(Pratt 1997; Pratt *et al.* 1999)
Phialophora radicicola[1]	*Gaeumannomyces graminis* var. *avenae* (Ophiobolus patch disease)	Grass	(Deacon 1973)
Pseudomonas aeruginosa[1]	*Pythium ultimum* (dampening off)	Cucumber	(Carisse *et al.* 2003)
Pseudomonas fluorescens 708	*Pythium*	Sugar beet	(Bardin *et al.* 2004)
Pythium oligandrum[1]	*Pythium ultimum* (dampening off)	Cress and sugar-beet	(McQuilken *et al.* 1990)
Scytalidium uredinicola[2]	*Endocronartium harknessii* (western gall rust)	Pine	(Currie 1995)
Sphaerellopsis filum[1]	*Melampsora* spp. (rusts)	Willow	(Morris *et al.*)
Sporidesmium sclerotivorum[2]	*Sclerotinia, Botrytis, Amphobotrys and Monilinia* spp.		(Mischke 1998)
Streptomyces spp.[2]	*Pythium ultimum var. ultimum*	Poinsettia	(Gracia Garza *et al.* 2003)
Taloromyces flavus	*Sclerotium rolfsii* (stem rot)	Beans	(Madi *et al.* 1997)
Trichoderma asperellim[1]	*Fusarium oxisporum* f.sp. *lycopersici* (Fusarium wilt)	tomato	(Cotxarrera *et al.* 2002)
Trichoderma harzianum[1]	*Botrytis cinerea, Sclerotinia sclerotiorum* and *Cladosporium fulvum*	Cucumber and tomato	(Elad 2000)

Biological Control Agent	**Pathogen/disease controlled**	**Crop**	**Reference**
Trichoderma harzianum[1]	*Fusarium udum* (wilt)	Pigeonpea	(Prasad *et al.* 2002a)
Trichoderma harzianum[1]	*Sclerotium rolfsii* (collar rot)	Tomato	(Dutta and Das 2002)
Trichoderma harzianum[1]	*Fusarium oxysporum*	Banana	(Thangavelu *et al.*)
Trichoderma koningii[1]	*Phytophthora parasitica*	Quandong (Australian native food)	(Warren and Ryder 2003)
Trichoderma viride[1]	*Rhizoctonia solani*	Cotton, tomato, okra and sunflower	(Mathivanan *et al.* 2000)
Trichoderma viride[1]	*Botrytis cinerea*	Strawberry	(Pratella and Mari 1993)
Trichothecium roseum[2]	*Sclerotinia sclerotiorum* (white mould)	Bean	(Huang *et al.* 2000)
Tuberculina maxima[2]	*Cronartium quercuum* f. sp. *fusiforme*	Slash Pine	(Kuhlman 1981)
Verticillium biguttatum[1]	*Rhizoctonia solani*		(Postma *et al.* 2003)
Verticillium chlamydosporium[1]	Nematodes	Barley	(Bordallo *et al.* 2002)
Verticillium lecanii[1]	Mites	Bees	(Shaw *et al.* 2002)

[1]slime-spored fungi or slime-celled bacteria (less likely to spread on the wind and cause allergies in man or other environmental impacts; (Cook and Baker 1996)
[2] dry-spored micro-organisms (Cook and Baker 1996)

2.4.1 Biocontrol agents

The use of microbes for replacing a synthetic chemical is demonstrated by the development of a mycoherbicide to control the noxious weed, Bathurst burr (*Xanthium spinosum*). NSW Agriculture 1994 has developed a herbicide for the control of this weed using the fungi *Colletotrichum orbiculare*. This mycoherbicide is applied using similar herbicide application techniques and equipment, but as this herbicide utilises a live microbe, it is perceived to be safer and would also represent a longer efficacy, providing the weed is present.

Similarly, biofungicides have been developed for the control of fungal diseases. A number of products based on *Trichoderma* sp have been developed world-wide and shown to be effective against a number of diseases. For instance, Trichodex™ is available for the control of *Botrytis* in Israel (Wilson 1997) and Croatia (Topolovec-Pintaric *et al.* 1999). Various spray regimes using AQ10™, a biofungicide of *Ampelomyces quisqualis* has been shown to effectively control powdery mildew on a number of crops (Sirca 2001) including roses (Pasini *et al.* 1997) and grapes (Daoust and Hofstein 1996; Hofstein *et al.* 1996). Bio-Save 11™ is based on a strain of *Pseudomonas syringae*, is available in the United States and has been shown to effectively control fruit decay in apples caused by *Botrytis cinerea* and *Penicillium expansum* (Janisiewicz and Jeffers 1997). Primastop™ is another biofungicide registered in the United States. This biofungicide uses a strain of *Gliocladium catenulatum* and is recommended for the control of damping-off on vegetables, and for root and stem rot diseases in vegetables and ornamentals (Niemi and Lahdenpera 2000).

Many mechanisms of action have been proposed for both bacterial and fungal biocontrol organisms. Winding *et al*. (2004) lists some key features for control mechanisms:

- Competitive advantage for resources, physical space and nutrients
- Production of antimicrobial agents (2,4-diacetylphloroglucinol {DAPG}, viscosinamide, pyoluteorin, zwittermicin A, kanomycin, phenazine-1-carboxylic acid, cyanide)
- Degradation of pathogenicity factors of pathogens.
- Production of chitinolytic and cellulolytic enzymes that degrade cellular components in fungi.
- Induction of plant resistance.

For both *Trichoderma* and *Bacillus* spp. as well as many of the others listed in Table 3, evidence exists that these biocontrol agents do not provide adequate disease control or suppression under all situations. Factors such as micro-climate, disease pressure, pathogen strain, crop health and cultural practices affect the ability of the biocontrol agents to sufficiently decrease losses from a disease.

2.4.2 Delivery and commercialisation of control vectors

The study of micro-organisms as biological control agents has raised several issues on methods of distribution. For example, (Maccagnani *et al.* 1999) used bees to distribute *Trichoderma harzianum* over a strawberry crop for control against grey mould (*Botrytis cinerea*). A similar technique was trialled in Geraldton waxflower for the control of flower drop (Beasley 2001). In the first instance, better distribution of *T. harzianum* and hence decreased disease severity was achieved through distributing the biocontrol agent through water suspension, however, this same control was not achieved in waxflower. Beasley (2001) attributed a number of reasons for the lack of disease control including reduced inoculum loading level compared to other studies with bees, more desirable nectar sources in the nearby locality at the time of the field experiment and/or undetectable inoculum levels at the flower surface. Another method of distributing the biocontrol agent is through seed treatments. (Tsahouridou and Thanassoulopoulos 2002) showed that *Trichoderma koningii* could be effectively distributed on tomato seed to control *Scleotium rolfsii* (dampening off). If seed treatments are to be used, care is required to choose a biocontrol agent that is rhizosphere competent. Additionally, normal storage time and temperatures may need to be altered to conserve the efficacy of the biocontrol agent. Other delivery systems are available, however, the limiting factor for many growers is the cost of applications and the use of available equipment and machinery.

It is well recognised that applying microbes to soil is a “hit and miss” process. Many reports in the literature (e.g. Tsahouridou and Thanassoulopoulos 2002; Downer *et al.* 2002; Prasad *et al.* 2002a; Bennett *et al.* 2003) discuss the problems associated with predation of applied microorganisms, and question the viability of altering soil microbial communities by the application of these microbes. One method for applying microorgansisms that is proving successful utilises inoculated composts. This is discussed later in the report.

Recently Dr Tony Vancov (NSW Agriculture, pers comm) and his team have developed a process whereby microorganisms are embedded within a clay matrix and enable the survival of microorganisms for over 12 months. Technologies such as this may be necessary for the application of microorganisms to soil to enable adequate survival and inoculation and micro-climate adaption.

The range of evidence of control success supports the theory that the use of micro-organisms to control disease requires strains to be carefully selected based on the pathogen, crop and growing region.

2.4.3 Disease suppressive soils

Many horticulturalists strive to induce disease suppression in their soils. This area of research is expanding and is only covered briefly in this review. Disease suppression can occur even when pathogens including *Fusarium oxysporum, Phythophthora cinnamomi, Gauemanomyces graminis* and *Rhizoctonia solani* are present (Stirling and Stirling 1997). Several mechanisms for disease suppression have been suggested, including colonisation of roots by disease suppressive arbuscular mycorrhizal fungi and disease suppressive bacteria. Abiotic suppression including changes in soil physico-chemical properties and also been suggested important (Stirling and Stirling 1997).

The colonisation of plant roots by arbuscular mycorrhizal fungi (AM fungi) can affect bacterial and fungal communities in soil and the rhizosphere (Johansson *et al.* 2004). The AM fungi can change the mycorrhizosphere by altering pH, by competing for nutrients, production of exudates of inhibitory and stimulatory nature, impact on plant growth, root exudation and soil structure. Filion *et al.* (1999) discusses the benefits of AM associations by studying the exudates of the AM fungi *Glomus intraradices*. The authors demonstrated that these exudates were inhibitory to the pathogen *Fusarium oxysporum*. Another key suppression mechanism for AM fungi is increased nutritional status of host plants (Johansson *et al*. 2004), thus rendering them more capable of withstanding attack. Although the authors also suggest that evidence is still lacking that this is a key protection mechanism.

Disease suppressive soils have been induced by the application of sulphate based fertilisers (Sturz *et al.* 2004). It was demonstrated that the root zone became colonised with bacteria in the genera *Bacillus* and *Pseudomonas* which inhibited potato common scab (*Streptomyces scabies*). Mulches and compost are also commonly used to increase the suppressiveness of soils, and this is discussed in the following section.

2.5 Mulches, compost, compost teas and vermiculture products

2.5.1 Compost and mulch

The organics industry has historically utilised composts and vermiculture products for fertiliser, weed control, disease suppression and improving soil structural, chemical and biological properties. This review will concentrate on the benefits resulting in plant disease control.

There is an increasing body of literature demonstrating the benefits of compost (when used as a mulch or soil additive) in suppressing a range of plant diseases. However, peer reviewed articles on the benefits of compost tea or similar extracts are still lacking (Chalker-Scott L. 2003). Chalker-Scott continues to discuss that a significant quantity of non-scientifically-published information on compost tea exists (4000 web pages utilising a Google search alone), and strongly urges better scientific validation of claims.

Agricultural practices have led to a decline in soil structure, and a corresponding increase in soil-borne plant diseases (Bailey and Lazarovits 2003). Use of composts and other organic amendments have been demonstrated to improve plant health and productivity.

Mature composts have shown scientific evidence of disease suppression (Hoitink and Boehm 1999; Chen *et al.* 1988) by supplying antagonistic microorganisms to pathogens. The use of compost made from vegetable and animal market wastes was recently shown to be highly suppressive to Fusarium wilt in tomato (Cotxarrera *et al.* 2002). Interestingly the authors showed that a peat mix with similar pH to the compost was highly conducive to the wilt. Utilising a small amount (10 % v/v) suppressive compost in the peat mix was adequate for transferring resistance. Cotxarrera *et al.* (2002) also demonstrated composted sewage sludge could suppress *Fusarium* during the early stages of plant growth. Reuveni *et al.* (2002) also describes the influence of compost on suppressing *Fusarium oxysporum* in sweet basil. Peat moss was again shown to be conducive to disease while autoclaving the compost nullifies its suppressiveness. Knudsen *et al.* (1999) demonstrated the use of mulch and other organic amendments for increasing the potential of disease antagonists.

Composted paper mill wastes have been shown to reduce disease symptoms of bacterial speck caused by *Pseudomonas syringae* in tomato plants (Vallad *et al.* 2003). Stone *et al.* (2003) also describe suppression of anthracnose (*Colletotrichum* sp.) using amendments with composted paper mill wastes.

Lumsden *et al.* (1986) suggest that increased microbial activity found in soil following composted sewage application increased suppression of pythium and rhizoctonia damping off. Garcia *et al.* (in press) has also shown that composted sewage sludge suppresses phytophthora and phyium with peas of peppers. The more mature composts were shown to be more effective. Dollar spot (*Sclerotinia homeocarpa*) in turfgrass was suppressed to levels equivalent to those using chlorothalonil by 3-weekly addition of compost (Boulter *et al.* 2002). The authors showed that storage of compost for 1 year did not impact upon its ability to suppress disease. Factors including increased microbial activity, microbial population dynamics, nutrient concentration and other chemical and physical factors were discussed as relevant to disease suppression.

Grobe (1997) interviews soil scientist Ralph Jurgens, who states that application of compost to soil can help stimulate microbial activity and soil fertility. Composted macadamia husk, a production waste product has recently been shown to increase microbial activity in soil. Van Zwieten *et al.* (2003), however, benefits to disease suppression were not studied. van Os and van Ginkel (2001) have demonstrated that suppression of *Pythium* is correlated with high microbial biomass and microbial activity, demonstrating the benefits shown by Van Zwieten *et al*. (2003) may induce disease suppressive soils.

2.5.2 Compost tea

Compost tea is broadly defined as an aqueous product arising from compost. Compost teas can be divided into three main categories. Teas arising from compost leachate, non-aerated fermented compost tea, and aerated fermented tea. Scheuerell and Mahaffee (2002) discuss the origins of compost tea as being an old garden practice of soaking seeds with “compost water” to prevent damping off.

Compost tea is viewed as a real alternative for disease control in organic farming (Scheuerell and Mahaffee 2002), however, levels of control are generally considered inadequate for conventional farming systems. Compost teas work by introducing a diverse range of microorganisms to agricultural systems, and the beneficial microorganisms out-compete the pathogens for nutrients (Wickland *et al.* 2001). In addition, compost teas may contain chemical antagonists such as phenols and amino acids. David (2001) describes other possible modes of action including induction of plant resistance and inhibition of spore germination.

One of the other key criticisms of compost tea, apart from the lack of scientifically published data, has been that there is a lack of quality control in the production of tea.

Can two tea’s ever be the same? Does the compost tea have to be the same?

The main limitation of farm-based production of compost tea is quality and sufficient monitoring of product efficacy (David 2001). In light of the fact that there are potentially thousands of species of microorganisms brewed up in tea, and current science only allows us to culture and identify a small handful of these microorganisms, how is it possible to guarantee one product (or one brew) will perform equally to the next brew. Perhaps the efficacy is not completely reliant upon the exact composition, however, there is again no literature to support this.

2.5.2.1 Non-brewed tea

The run-off or leachate from compost piles has traditionally been considered a nuisance, as leachate often required containment and treatment to remove metals, pathogens or other contaminants (Peot and McIntyre 2000). The authors investigated leachate from a composting operation, and developed a pasteurisation technology to reduce pathogens to legal requirements. This compost tea however was sold as a foliar and soil fertiliser, and disregarded the potential microbial benefits of the tea. No claims of pathogenic control were made from this product.

2.5.2.2 Brewed tea

This literature review has uncovered a range of articles regarding the benefits of compost tea, how to make it, and which brewing system is the best. Wickland *et al.* (2001) discusses factors for consideration in preparing a brew, and applying for disease control:

- Maturity of compost,
- Composition,
- Environment compost was produced,
- Temperature of brew,
- Brewing length,
- Method of brewing,
- Timing and frequency of application.

Table 4 shows that there is a wide range of microorganisms potentially present in compost tea. Which ones are effective in controlling disease however, is unknown.

Table 4: Principal microbial species described in compost teas

General microbial group		References
Nitrogen fixers	*Azotobacter*	(Merrill and McKeon 1998)
	Mycobacterium	(Merrill and McKeon 1998)
	Azospirillum	(Merrill and McKeon 1998)
	Rhizobia	(Merrill and McKeon 1998)
	Anabaena	(Merrill and McKeon 1998)
	Nostoc	(Merrill and McKeon 1998)
	Escherichia (and *E.coli*)	(Merrill and McKeon 1998; Bess 2000)
	Bacillus	(Brinton *et al.* 1996); (Wickland *et al.* 2001)
Cellulolytic microbes	*Trichoderma*	(Brinton *et al.* 1996; Merrill and McKeon 1998)
	Actinomycetes	(Brinton *et al.* 1996; Bess 2000)
Others	*Pseudomonas*	(Brinton *et al.* 1996)
	Serratia	(Brinton *et al.* 1996)
	Penicillium	(Brinton *et al.* 1996)
	Enterobacteria	(Brinton *et al.* 1996)
	Staphylococcus	(Brinton *et al.* 1996)
	Actinomycetes	(Brinton *et al.* 1996; Bess 2000)
	Sporobolomyces (yeast)	(Wickland *et al.* 2001)
	Cryptococcus (yeast)	(Wickland *et al.* 2001)
	Salmonella	(Bess 2000)

Wickland et al., (2001) from Washington State University undertook a controlled experiment investigating aerobic and anaerobic brews and their efficacy against damping off diseases including *Fusarium*, *Pythium* and *Rhizoctonia*. The authors claimed that although some statistical evidence of control of disease was obtained, data was still largely inconclusive.

Compost tea applications to strawberries in the USA have provided some control of fruit rotting diseases (Sances and Ingham). Touart (2000) describes several instances where observed improvements in crop health have been shown with the application of compost tea. Gray mould on beans was controlled with tea. Grobe (1997) describes the use of compost tea for soil application. By developing a protective layer around the plant roots, disease organisms and nematodes could be controlled. Brinton and Droffnew (1995) describe control of powdery mildew (*Uncinula necator*) in glasshouse-grown grapes using extracts of cattle and grape pomace compost.

In an Australian study, David (2001) describes the production and application of compost teas in vegetable production systems, but no benefits to production or disease suppression were described.

2.5.2.3 Inoculated compost

Compost has been used as a host for the fungal antagonists *Verticillium biguttatum* and a non-pathogenic isolate of *Fusarium oxysporum* (Postma *et al.* 2003). These isolates were inoculated into a range of composts, and high survival rates were found after 3 months. The authors considered application of antagonists via compost as a real option for disease control.

Similarly, Wu (1998) demonstrated inoculation of potting mix with suppressive organisms isolated from swine manure compost significantly reduced *Rhizoctonia solani*, *Phytophthora capsici* and *Pythium aphanidermatum*. Amendments included *T. harzianum*, *T. koningii* and *B. subtilis*. Again, autoclaving the amended potting mix nullified the suppressive nature of the amendments.

2.5.2.4 Vermiculture products

Both liquid extracts and worm castings have received much interest in Australia as soil additives and crop improvers. Several vermiculture operations exist at commercial scale taking wastes from the food industry, local Council operations, and effluent treatment plants. Hansen (2001) describes the use of vermiculture products in Australia, and gives some examples of improved yields in vineyards. No scientific literature, however, was uncovered on the benefits of either of these products in reducing incidence of disease.

2.6 Surfactants and biosurfactants

The use of surfactants in agriculture is primarily as adjuvants to decrease the surface tension of water and increase the contact between the active ingredient and the plant/soil. Recently, however, Irish *et al.* (2002) discusses the use of surfactants in their own right as having disease control properties.

Surfactants (synthetic) and biosurfactants (produced by fungi and bacteria) both have potential for disease control. Irish *et al*. (2002) describes the use of a range of surfactants against white rust (*Albugo occidentalis*) in spinach. All surfactants significantly reduced disease and two products (Naiad and Sodium dodecyl sulfate) were comparable to fungicides.

Several studies have shown the effectiveness of surfactants against root-infecting zoosporic plant pathogens, including *Pythium aphanidermatum* on cucumber and *Phytophthora capsici* on peppers (Stanghellini and Tomlinson 1987; Stanghellini *et al.* 2000), and *Phytophthora* root rot of citrus (Mickler *et al.* 1998). Tomlinson and Thomas (1986) found the melon necrotic spot virus disease of cucumber which is transmitted via the zoospores of the fungus vector (*Olpidium radicale*) was controlled through the use of surfactants. A number of authors have shown effective disease control through the addition of surfactant to the nutrient solution used in hydroponic systems (Tomlinson and Thomas 1986; Stanghellini *et al.* 1996; Stanghellini *et al.* 2000; Stanghellini *et al.* 1996).

Irish *et al*. (2002) describes zoospore lysis as a proposed mechanism of surfactants, leading to reduced infection by oomycetes. The effective control of many zoosporic pathogens by surfactants and biosurfactants is attributed to the zoospore which represents the weak link in the life cycle of these pathogens because they have no cell wall (Stanghellini 1997). These spores are vulnerable as surfactant action through its uptake into the plasma membrane causes zoospores to rupture (Stanghellini and Miller 1997).

2.7 Antifungal compounds and mycobiocides

Plants use a variety of chemicals to defend against pathogen invasion. For example, cuticles contain antifungal chemicals, such as; benzoxazolinone compounds, coumarin derivatives, phenolics, alkaloids and proteins, which antagonise fungi (Martin 1964). Pathogens counter these chemical defenses by use of their own enzymes, toxins and growth regulators (Agrios 1997) (e.g. *Botrytis cinerea* secretes pectic and other hydrolases to degrade cell walls).

Antifungal antibiotics and plant growth regulators can be used to control postharvest diseases caused by fungi. The antibiotic, Nystatin (100 μg/L), applied as a dip or spray has been used successfully against *B. cinerea* on orchid flowers (Frank *et al.* 1959 cited by Eckert and Sommer 1967). Also Pyrrolnitrin (12 - 200 mg/L), an antibiotic isolated from *Pseudomonas cepacia*, significantly reduced postharvest lesion development caused by *B. cinerea* on cut rose flowers (Hammer *et al.* 1993). Application of gibberellic acid (GA_3; 20 or 346 mg/L) to cut rose flowers has been reported to control botrytis blight (Shaul *et al.* 1995a; Shaul *et al.* 1995b). It is thought that GA_3 inhibits the senescence-related increase in cell membrane permeability. In turn, this reduces leakage of nutrients from the tissue and thereby suppresses blight development (Sabehat and Zieslin 1994; Elad 1997).

2.8 Other products

A number of other products have been identified in the literature. These could be classified as home products as articles on these products are predominantly found in popular press rather than scientific literature. Products include baking soda solutions, clay preparations, milk, whey and plant extracts (e.g. molasses, seaweed, neem, tea tree and eucalyptus oil). These products are worthy of further investigation as evidence exists that these products have been used historically and although the degree of control of disease varies considerably, further scientific evaluation may assist in determining the mode of action for these products and allow further development.

In recent years, scientific research has begun on the use of baking soda or bicarbonate solutions for disease control as evidenced by a small number of scientific papers available on the topic. Even Cornell University has developed the Cornell Fungicide Formula which is based on baking soda and horticultural oil. The use of baking soda as a fungicide is not a recent discovery, with reports of its use in the 1930s (Kuepper *et al.* 2001). A number of bicarbonate products have been investigated including ammonium-, sodium- and potassium- bicarbonates. These products have been shown to control fungal diseases on cucurbits (Ziv and Zitter 1992). Other fungi controlled by bicarbonate solutions include *Penicillium digitatum* (citrus green mold) on lemons and oranges (Smilanick JL *et al.* 1999); *Oidiopsis taurica* (Leveillula taurica mildew) on pepper plants (Ziv *et al.* 1994); *Sphaerotheca macularis* (powdery mildew) on strawberry (Vecchione A *et al.* 2002) and *Sphaerotheca pannosa* (powdery mildew) on roses (Tjosvold SA *et al.* 2001). These products appear to provide disease control through pH modifications at the plant surface. Ecocarb®, a potassium bicarbonate product is available in Australia and has been shown to be relatively effective against powdery mildew in grape (Crisp *et al.* 2002). Additional applications of sodium bicarbonate were required to control powdery mildew on tomatoes in comparison with sulphur (Demir S *et al.* 1999). The impacts on the environment due to the requirement of additional tractor or equipment movements to obtain similar (or acceptable) disease control need to be assessed.

Clay preparations such as Myco-Sin® and Ulmasud® have been shown to effectively control fungal diseases on grape berries (Schmitt *et al.* 2002; Hofmann 1996), and fire blight in apples (Plagge and Rommelt 1997; Rommelt *et al.* 1999). These products appear to succeed in controlling disease through the increase in Aluminium at the surface of the plant and increases in the uptake of this element as a result of the acidic application solution (Enkelmann and Wohlfarth 1994). This increase in Aluminium and the acidic pH would result in an environment unsuitable for the germination of fungal spores. There is strong evidence from Europe that these products are useful in cool climates, however, these products are not yet available in Australia (Parlevliet and McCoy 2001). The side effects of using ‘natural’ products are relatively unknown. In this instance, Ulsamud® has been shown to be detrimental to predatory mites (Siggelkow and Jackel 1998).

Cow's milk has been shown to be effective against powdery mildew (*Sphaerotheca fuliginea*) in greenhouse grown zucchini (Bettiol 1999). The author attributes the controlling mode of action in this instance as possibly being a direct effect of milk due to its germicidal properties or the salts and amino acids contained in milk providing the controlling mechanism. Alternatively, Bettiol (1999) reasons the application of milk may induce systemic acquired resistance in the crop (refer section 2.9). In South Australia, a research program is investigating a number of alternative fungicides (Crisp *et al.* 2002). This study which is concentrating of finding alternatives for the grape and wine industry for control of powdery mildew found milk and whey products were the most successful products trialled so far. The study team reasons milk and whey protein may feed microbes on the grape and leaf surface which then compete for space and may even consume mildew spores (Crisp 2002; Westney 2002).

Limited data exists for natural alternatives to fungicides such as seaweed and plant oil extracts (Washington *et al.* 1999). The authors describe experiments on a range of alternative products for the control of fruit rot in strawberries including tea tree oil and seaweed extracts. They concluded tea tree oil provided some of the best control for the alternatives, however, it failed to control all of the rots, did not increase fruit yields and control was lower in comparison to conventional fungicides. In this study, the seaweed extract did not effectively control any of the disease-causing organisms. While the alternative products used in the this study did not provide similar disease control in comparison to conventional fungicides, this study did show there is some potential for these products and further investigation is required. Washington *et al*. (1999) discusses that changes in formulation may improve efficacy. Additionally, the combination of alternative products may provide adequate control (e.g. *Trichoderma* with tea tree oil). The use of plant extracts such as tea tree oil at concentrations required for fungicidal activity has also been shown to taint thin skinned fruit such as blueberries (Gordon Stovold, unpublished data), thus limiting the potential uses of these products. Other products have begun to be tested by scientists for their ability to suppress diseases such as fish emulsion and sugar (Neeson 2001).

Milsana®, a product based on plant extracts from Giant Knotweed (*Reynoutria sachalinensis*) have been reported to effectively control a number of fungal diseases including powdery mildew (*Sphaerotheca fuliginea*) on cucumber (Daayf *et al.* 1995) and powdery mildew (*Uncinula necator*), downy mildew (*Plasmopara viticola*) on grape (Schilder *et al.* ; Herger and Klingauf 1990; Schmitt *et al.* 2002). However, as with Ulmasud®, detrimental effects against mites have been reported with the use of Milsana® (Schuld *et al.* 2002; Siggelkow and Jackel 1998).

Polymer coatings or anti-transpirants may act as an artificial barrier on plant surfaces to minimise fungal hyphae invasion (Ziv and Hagiladi 1993). Most of these products are non-phytotoxic, permeable to gases, resistant to weathering for at least 1 week and are also biodegradable (Ziv and Zitter 1992). Limited information on disease control was found in the literature in using these products. Powdery mildew caused by *Oidium euonymi-japonica* was adequately controlled by a number of polymer coatings (Ziv and Hagiladi 1993) as was a range of foliar diseases on cucurbit (Ziv and Zitter 1992). Further research is warranted in determining effective polymer products that would also be suitable for use in the Organics Industry.

2.9 Induced resistance and genetic controls

Similar to the use of cats for controlling rodents, the history of plant breeding can be shown to date back to ancient Egypt whereby seeds were collected from plants which demonstrated desirable traits such as increased yield, larger fruit and disease resistance. These seeds were used to produce the following year's crop with the same selection process occurring and while at the time, knowledge of plant genetics was limited, an overall improvement in yields or quality was achieved. Plant cultivars have been shown to differ in their susceptibility to disease resistance (Mount and Bermnan 1994). In many instances desirable traits such as yield and quality may be linked to disease susceptibility thereby selection for one desirable trait may inadvertently select for an undesirable trait.

The pathogenic *Phytophthora* species possibly cause some of the most devastating disease losses in agriculture. For example, *P. infestans* caused the potato famine in the 1840s – 1850s. In Australia, *P cinnamomi* has been listed as a key threatening process for native species under the *Threatened Species Conservation Act 1995*. The threat of the Phytophthora root rot diseases has resulted in the selection of a number of resistant rootstocks for a variety of crops (e.g. macadamia, avocado, roses, eucalypts) thereby reducing the risks of losses from this disease. Plant genetics has allowed other traits (e.g. fruit size, flower colour) to be selected in cultivars and when grafted onto a resistant rootstock, a robust plant is produced.

In modern plant genetic research, more sophisticated techniques are used to select the desirable traits. For example, the gene from *Bacillus thuringiensis* (Bt) that provides control against insects has been incorporated into cotton. Experimentation has lead to this transgenic crop being grown commercially in Australia for approximately 8 years (CSIRO).

Induced defense mechanisms include accumulation of antifungal compounds such as phytoalexins and phenolics. Structural modification of cell walls include formation of cork and abscission layers, deposition of gums, formation of tyloses, and the hypersensitive responses where free radicals and lipoxygenase are released and accumulated (Agrios 1997). In postharvest disease control, heat treatment, wounding, exposure to gamma irradiation or UV-C light, activity of some microbial antagonists and attenuated strains and certain natural chemical compounds can elicit disease resistance mechanisms in crops (Wilson *et al.* 1994; Joyce and Johnson 1999).

Systemic acquired resistance (SAR) is part of the inducible natural defense response in plants (Kessman *et al.* 1994). The first recognition of plant defense in response to pathogen infection was with *B. cinerea* (Ray 1901; Beauverie 1901). Salicylic acid (SA) and other benzoic acid derivatives are endogenous chemical signals responsible for mediating plant defenses (White 1979; Ryals *et al.* 1994). Such chemicals can be applied to plants to elicit natural disease resistance, but with varying efficacy. Exogenous applications do not always work due to crop intolerance to some chemicals (Kessman *et al.* 1994). SA production by plants might be monitored and used as an index of downstream SAR gene expression capacity in different genotypes (Ryals *et al.* 1994).

2.10 Cultural controls

Cultural controls include pre- and postharvest hygiene, site selection, preharvest agronomic variables such as plant nutrition, crop husbandry and prevention of physical damage (Olkowski *et al.* 1991). Hygiene measures involves the removal of dead and decaying plant material and weeds from the crop, regularly cleaning and disinfecting equipment and machinery (e.g. harvesting equipment) and using clean water and containers. These activities lower the level of inoculum of pathogens (Agrios 1997; Coates and Johnson 1997).

Plant nutrition is also a well studied area of plant health and the effect of nutrients on plant disease can be divided into two broad categories: phylloplane nutrients and whole plant nutrition. Nutrients on the surface of plant tissue affect the germination and infection of plant pathogens. For example, Yoder and Whalen (1975) reported *B. cinerea* spores need 4 to 8 h of exposure to nutrients to germinate and an additional 8 to 16 h to infect the surface of cabbage leaves. Wounding of tissue was able to satisfy the nutrient needs of *B. cinerea* spores. Bean leaves with damaged cuticles were more susceptible to invasion by *B. cinerea* (Mansfield and Deverall 1974). Natural abrasion allows nutrients to lead into inoculum droplets. In turn, vitalised pathogens can overcome potential inhibitors of infection, such as other micro-organisms and wax on leaf surfaces (Rossall and Mansfield 1981).

Mineral nutrition, waterlogging, extreme pH and frost damage affect susceptibility of plants to fungal invasion (Marschner 1995; Harrison 1988). Calcium has been identified as a nutrient that can markedly affect the physiological condition of fruits and vegetables (Bangerth 1979) and thus their susceptibility to disease.

Disorders associated with calcium deficiency are mediated by impaired membrane function and disruption to compartmentation (Bangerth 1979). Calcium polygalacturonates are required in the middle lamella for cell wall stability (Marschner 1995). The calcium cross-linkages of middle lamella pectins help maintain cell wall structure (Bangerth 1979). Cell walls play an important role in the resistance of plant tissue to infection by pathogens (Chardonnet *et al.* 1997). Parasitic fungi release pectolytic enzymes to dissolve the middle lamella. These enzymes are strongly inhibited by calcium (Bateman and Lumsden 1965). However, Kaile *et al.* (1991, 1992) suggest that calcium released from cell walls by pectic enzymes secreted by *B. cinerea* could facilitate infection by causing plant cell death through cytotoxicity.

Increased solute leakage characterises membrane degradation during senescence (Ferguson 1984). For example, enhanced solute leakage from flower tissue has been shown by Hanson and Kende (1975) for morning glory and by Mayak *et al.* (1977) for carnation. The nutrients released are available to stimulate pathogen germination and infection.

Calcium has been shown to reduce the severity of disease. For example, calcium reduced decay in apples by maintenance of firmness, a direct ionic effect, and/or an effect on total phenolics (Conway and Sams 1984). They argued that maintenance of fruit firmness alone would not reduce disease, and reasoned that the chemical composition of the cell wall was the determining factor. Ferguson (1984) found that calcium application retarded fruit ripening, respiration and ethylene production, fruit softening, colour changes and solute leakage. Poovaiah (1986) determined that calcium delays senescence and mitigates against physiological disorders of fruits and vegetables largely via a positive relationship between calcium and membrane integrity. Conway and Sams (1984) disproved their proposition of calcium having a direct effect on fungal growth. Fungal growth *in vitro* or on juice from calcium-treated fruit was not effected by calcium chloride ($CaCl_2$). Elad and Volpin (1988) believe that calcium bound in the middle lamella has a direct effect on pectic enzymes released by *B. cinerea*. Disease severity was reduced when calcium was added to pulsing solutions of roses. Furthermore, Elad and Volpin (1988) and Volpin and Elad (1991) determined that ethylene production by rose flowers from plants fertilised with calcium was lower. However, disease severity increased when Elad and Volpin (1988) sprayed rose flowers with calcium chloride solution because the pathogen used the solution as a nutrient source. Chardonnet *et al*. (1997) reported that pretreatment of grapes with a calcium chloride dip had no effect on infection rate. Chardonnet *et al*. (1997) correlated the decrease in total pectin of infected grape tissue to degradation by enzymes produced by *B. cinerea*. Shaul *et al.* (1992) suggests that *B. cinerea* is unable to utilise pectate, to produce pectinase enzymes, in the presence of calcium.

2.11 Integrated Pest Management (IPM)

Integrated Pest Management (IPM) as the name suggests, is a system of pest management that endeavours to incorporate all the various control measures available to create an effective and environmentally sensitive approach to the control of pests (United States Environmental Protection Agency 2004). This strategy relies on the recognition of an economic threshold that indicates when a pest population requires control to prevent declines in yields and thereby net returns. The principle of an IPM program is to utilise natural mortality events such as natural predators combined with a range of other practices such as cultural controls (e.g. weed removal), biological control, genetics and in conventional farming systems the judicious use of synthetic chemicals. Organic farming systems make use of all of these control techniques with the exception of synthetic chemicals whereby pesticides produced from natural sources are permitted.

Olkowski *et al*. (1991) details a number of commonsense pest control measures that are suitable for use in organic farming systems. The authors outline four main strategies:

- Designing or redesigning the landscape or physical structure (e.g. monocultures attract pests due to large food source);

- Modifying the habitat to reduce the pest's food, water and shelter and increase the habitat for natural predators.
- Changing human behaviour by altering cultural methods such as cultivation, weeding, mulching and increasing inspections and monitoring for pest populations.
- Direct suppression of pests through physical and mechanical controls (e.g. weed removal, netting); biological control and only when necessary using the least toxic chemical method (inorganic pesticides include copper and sulphur; botanical pesticides include nicotine, pyrethrum and derris).

Macdonald and Stovold (1995) explain that the process of IPM is not as complex as it is sometimes made out to be. Most horticulturalists follow a number of steps to determine whether a disease problem exists. Monitoring, diagnosing, choosing and applying an appropriate control method and continued monitoring are the basic steps to in IPM.

Much research has been conducted in recent years on the subject of IPM or its components as evidenced by the large number of papers identified during literature searches. In many instances, the research conducted has occurred in developing countries which could be indicative of the associated costs of obtaining synthetic chemicals in these countries. However, these research papers outline various methodologies that do not require elaborate or costly equipment to implement, and thereby are strategies available for all growers.

Additionally, community perceptions on the use of synthetic chemicals are changing. For instance, a nation-wide household survey undertaken in Italy, found strong evidence that households prefer foods produced under environment-friendly production methods such as organic and integrated pest management (Scarpa and Spalatro 2001).

3. Products identified through national expression of interest call

A total of twenty seven responses were obtained from the press releases. From the responses, a range of products have been identified that are either currently available in Australia, or would be relatively easy to obtain. The information provided in Table 5 includes products that are based on biological control, home remedies and researched control mechanisms. The order of the products given is purely chronological, and does not reflect the level of confidence in these products. For many of the products, it was not possible to obtain information on the content.

The product trade names in this publication are supplied on the understanding that no preference between equivalent products is intended and that the inclusion of a product does not imply endorsement by NSW Agriculture over any other equivalent product from another manufacturer.

Recognizing that some of the information in this document is provided by third parties, the State of New South Wales, the author and the publisher take no responsibility for the accuracy, currency, reliability and correctness of any information included in the document provided by third parties.

ALWAYS READ THE LABEL Users of agricultural (or veterinary) chemical products must always read the label and any Permit before using the product, and strictly comply with the directions on the label and the conditions of any Permit. Users are not absolved from compliance with the directions on the label or the conditions of the permit by reason of any statement made or not made in this publication.

Table 5: Products identified for disease control

Company/contact[1]	Trade names of products Identified (available in Australia)[2]	Potential Products Identified[3]
1	Vigor-Cal™	
2		baking soda, chamomile tea, seaweed, molasses, rhubarb, eucalyptus woolwash, parsley water
3		Horsetail (*Equisetum arvensa*) teas (both fresh and fermented)
4	Biomex Plus® with Trichoderma VAM-OZ® (Glomus intaradices)	
5		Structured water
6	Effective Micro-organisms (EM)	
7	Citrofresh® Croplife®	
8		Compost teas, wood ash (for changing pH in soil)
9, 10	NutriTech products – see below	
11	Liquicop® Copper Fungicide	
12	Citrox® 14W	
13		Potassium permanganate, Bicarbonate of soda, worm castings
14	Nutri-life Trichoshield™ Nutri-life *B. sub*™ Nutri-life 4/20™	Eco-Dyne
15	Trich-A-Soil® EcoCarb® Synertrol® Horti Oil Acadian™ Aminogro®	Hay Rite (*Bacillus amylolquifaciens*), Pr70 Release (*Penicillium radicum*)
16	Cornell Fungicide Formula (baking soda, horticultural oil)	

Company/contact[1]	Trade names of products Identified (available in Australia)[2]	Potential Products Identified[3]
17		Baking soda, Compost teas, Milk and whey, *Brevibacillus brevis*, *Reynoutria sachalinensis* plant extracts (Milsana®)[2] clay preparations (Myco-Sin®)[2]
18	BD501	yoghurt culture, molasses, fish emulsion, worm juice, biodynamic silica (BD501), vinegar, hydrated lime, condy's crystals
19		Compost teas (made from cow manure & timber wastes)
20		Various biological controls (e.g. *Bacillus licheniformis* and/or *B. subtilis*)
21		colloidal silver, colloidal copper and seaweed extracts
22		Casuarina tea
23		colloidal silver
24		pectin copper complex
25		Eucalyptus or tea tree oil (against Fusarium)
26	Tri-D25®	
27	Carbo-Max® Silica-K®	

[1]Sources of information may be confidential, company/contact details may be provided after consultation with the authors
[2]Product descriptions are provided in Appendix 3
[3]Products/formulations/ideas have been identified by companies/growers/individuals as potential products for controlling disease, products are not known to be commercially available in Australia.

The exact nature of most of these products was not disclosed by the Companies; however it was clear that many of them contained micro-organisms that have already been discussed in the literature review.

No data on disease control was provided for any of these products. Thus no ranking of their efficacy was undertaken. It was, however, possible to broadly rank the general technologies using data published in refereed journals and non-refereed publications. The technologies were ranked not only according to the number of relevant publications found, but also on the significance of the data presented and sentiments of authors in review articles. Three categories for ranking technologies were chosen: 1) Technology highly relevant; 2) Technology shows promise; 3) Not enough information currently available.

Technologies highly relevant to disease control

- Biological control (level of evidence varies greatly, with *Trichoderma harzianum* and *Bacillus subtilis* in particular having significant evidence).
- Compost
- Compost inoculated with Biological control agents
- Surfactants and biosurfactants
- Antifungal compounds

Technology shows promise

- Compost tea
- pH modifiers
- Foliar calcium
- Foliar silicone
- Organic amendments (eg. Milk products, molasses, fish emulsion, sugar)
- Polymer coatings

Not enough information currently available

- Vermiculture products
- Plant extracts (eg. tea extracts, rhubarb)
- Seaweed extracts
- Colloidal silver
- Potassium permanganate

4. Requirement for registration

Many of the products listed in Table 5 have disease control capabilities; however, the requirement for registration prohibits the Companies claiming this. A number of products listed are of biological origin and fall into the *Agricultural and Veterinary Chemicals Code* (Agvet Code) definition of an agricultural chemical product and therefore require regulation by the NRA. Chemicals (and biologicals) are assessed to avert their becoming contaminants and posing unacceptable risks to the Australian environment (Rabbidge and Fan 2004).
In many cases, biological products have different properties from conventional chemical products and therefore separate guidelines and data requirements have been prepared to more appropriately address the potential risks posed by biological agricultural products. These guidelines can be read in detail on the APVMA web page. (http://www.apvma.gov.au/guidelines/bioagprod.shtml).

The guidelines go on the state "Many biological pesticides have a narrow host range. They may target specific pests, exhibit limited non-target effects and thus pose minimal adverse effects on humans and the environment. In the case of products that are degraded relatively readily in the environment, biological products may pose minimal long-term environmental effects. The NRA recognises that some biological products, due to their inherently lower risk, may thus be more desirable than some synthetic pesticide chemicals. However, not all biological products are necessarily safer products and it is the responsibility of the NRA to evaluate fully the risks associated with all products that fall under its jurisdiction."

Some agricultural chemical products are also covered by other legislation. Applications for the following groups of products must also satisfy the requirements of the organisation or legislation indicated:

- Classical biological control agents — *Biological Control Act 1984*;
- Genetically modified organisms — Genetic Manipulation Advisory Committee (GMAC) or its replacement organisation; and
- Imported biological agents — *Quarantine Act 1908* and *Administrative Arrangements, Wildlife Protection (Regulation of Exports and Imports) Act 1982*.

The guidelines continue to discuss that applicants should check that their product is regarded by the NRA as a biological product before adopting the biological products data requirements.
Four major groups of biological products were listed:

- Group 1— biological chemicals (e.g. pheromones, hormones, growth regulators, enzymes and vitamins)
- Group 2 — extracts (e.g. plant extracts, oils)
- Group 3 — microbial agents (e.g. bacteria, fungi, viruses, protozoa)
- Group 4 — other living organisms (e.g. microscopic insects, plants and animals plus some organisms that have been genetically modified)

Certain classes of product were specifically exempted from registration under Schedule 3 of the Agvet Code Regulations according to the guidelines. These include:

- Soil ameliorants,
- Fertilisers,
- Some classes of pest management lures,
- Domestic disinfectants,
- Hay,
- Silage or legume inoculants based on bacteria or enzymes,
- Cut flower preservatives,
- Predatory insects and mites, and
- Macroscopic parasites.

Plant growth-stimulating products where the label does not make claims for pest control or specific growth regulation are covered under State/Territory fertiliser regulations and do not require registration by the NRA. However, products based on plant hormones do require registration.

Registration guidelines state that the overall level of risk posed by a microbial pesticide used in agriculture is related to the possible hazards associated with the organism and the degree of exposure to humans and the environment. Potential hazards of microbial agents include toxin production, pathogenicity/infectivity, host range expansion and competition with existing microbial flora. Exposure factors include survival of the organism, replication in the environment, dissemination, persistence and horizontal gene transfer. Unreasonable risks include adverse effects on humans, commercially/economically important species, ecologically important plant and animal species and endangered plant and animal species. The origin of the microbial organism is also important, with organisms from overseas countries requiring closer scrutiny than Australian indigenous organisms. This further supports the conclusion that biocontrol agents should be isolated locally. The efficacy of imported, or in fact non-local microbial species, has been questioned by Dr Percy Wong, NSW Agriculture, in favour of isolating local species.

5. Discussion and recommendations

Organic horticulturalists understand the importance of a healthy fertile agroecosystem to provide adequate nutrients, water and support for plants. A health system also protects crops from pests and diseases. A diverse, abundant soil fauna (including bacteria, fungi, mites, earthworms) has been shown to outcompete and exclude pathogenic organisms in many trials around the world. The use of copper for disease has been shown to impact on soil health, thus reducing the soils natural ability to buffer against disease. The Organic Registration bodies are justified in their attempts to reduce inputs of copper through fungicide usage, considering the potential negative effects of heavy metals. The question however remains: What can organic horticulturalists use to prevent or treat disease?

The report reviewed a large range of biological controls. Two micro-organisms however stood out, as they are currently widely used and studied for disease control around the world: *Trichoderma harzianum* (a fungi) and *Bacillus subtilis* (a bacterium). Exceptional evidence exists that these micro-organisms can reduce the severity of a range of plant pathogens. These, along with other biological control organisms have been shown to operate through processes including competition for available nutrients, parasitism and though the production of antifungal or anti bacterial agents. Problems with the delivery of these micro-organisms have been discussed. It was shown that delivery of the micro-organisms in mature compost can be effective at controlling soil borne diseases such as Phytophthora and novel ways of application of immobilised microorganisms has been discussed. The importance of obtaining local strains of disease control microorganisms was stressed, therefore researchers and suppliers of these products will need to work together to develop the most appropriate mix of micro-organism for the task at hand.

Simply put, the "silver bullet" approach is unlikely to work with these biocontrol agents! If the approach is adopted, scientists and end users are likely to be left disappointed.

Compost and mulches have been shown effective in reducing many soil borne diseases. Compost tea which is a compost liquid extract has been much publicised, with many claims regarding its efficacy for improved plant growth and disease control. Many of the claims are not substantiated with scientifically published evidence. Although this is not proof that the product is ineffective, it does nevertheless raise several doubts. Some of the key questions that have been raised concerning compost tea include its method of production, reproducibility of product, and quality of data generated in trials. Greater scientific scrutiny of "tea" products is urgently required.

Registration of alternative products for disease control is a major challenge, as often significant information will need to be gathered by the provider, which is a costly exercise. This report discusses some of the requirements for registration. All biological products will need registration; however, some of the "home remedies" such as household disinfectant, some essential oils, bicarbonate, milk products etc are exempt.

It is unfortunate that many products that may have disease controlling properties are either not available in Australia, or are currently unregistered, and marketed as "soil amendments." The authors of this report strongly urge the RIRDC, the organic registration bodies, and other Industry R&D organisations to closely investigate the issue of registration of alternative products, as most of the providers will be unlikely to fund the required work. Clearly, registration will be required, but significant benefits including proper evaluation of the products can be simultaneously undertaken. There may be pathways that could be explored with the NRA whereby products with similar micro-organisms marketed by different companies could be reviewed together.

The majority of products identified from the national call have not been proven under independent scientific experiments, and providers of the technologies were reluctant to provide any information on their products' efficacy against disease control, thereby contravening registration requirements.

References

Agrios GN (1997) 'Plant Pathology.' (Academic Press Inc.: San Diego, California)

Alva, AK, Huang, B, Paramasivam, S (2000). Soil pH affects copper fractionation and phytotoxicity. *Soil Science Society of America Journal* **64(3)**, 955-962.

Avcare (2003). Fungicide Activity Group List.
Bailey, KL, Lazarovits, G (2003). Suppressing soil-borne diseases with residue management and organic amendments. *Soil and Tillage Research* **72(2)**, 169-180.

Bangerth, F (1979). Calcium-related physiological disorders of plants. *Annual Review of Phytopathology* **17**, 97-122.

Bardin, SD, Huang, HC, Moyer, JR (2004). Control of Pythium damping-off of sugar beet by seed treatment with crop straw powders and a biocontrol agent. *Biological Control* **29(3)**, 453-460.

Basham, JT (1973). Heart rot of Black Spruce in Ontario. II. The mycoflora in defective and normal wood of living trees. *Canadian Journal of Botany* **51(7)**, 1379-1392 + 3 pl.

Bateman, DF, Lumsden, RD (1965). Relation of calcium content and nature of the pectic substances in bean hypocotyls of different ages to susceptibility to an isolate of *Rhizoctonia solani*. *Phytopathology* **55**, 734-738.

Beasley DR (2001) Strategies for control of *Botrytis cinerea* on Geraldton waxflower flowers. Department of Plant Production. The University of Queensland, Gatton College, Lawes, Qld.

Beauverie, J (1901). Le *Botrytis cinerea* et la maladie de la toile. *CR Academy of Science Paris* **128**, 846-849, 1251-1253.

Bennett, AJ, Leifert, C, Whipps, JM (2003). Survival of the biocontrol agents Coniothyrium minitans and Bacillus subtilis MBI 600 introduced into pasteurised, sterilised and non-sterile soils. *Soil Biology and Biochemistry* **35(12)**, 1565-1573.

Beradze, LA, Dzimistarishvili, NB (1985). Results of testing some fungicides against grey mould on hazelnuts. *Subtropicheskie-Kul'tury* **2**, 156-157.

Bess, VH (2000). Understanding compost tea. *BioCycle* **41(10)**, 71-72.

Bettiol, W (1999). Effectiveness of cow's milk against zucchini squash powdery mildew (Sphaerotheca fuliginea) in greenhouse conditions. *Crop-Protection* **18(8)**, 489-492; 23 ref.

Beyer, WN, Chaney, RL, Mulhern, BM (1982). Heavy metal concentrations in earthworms from soil amended with sewage sludge. *Journal of Environmental Quality* **11(3)**, 381-385.

Biological Famers of Australia (2003) (Biological Farmers of Australia Co-op Ltd: Toowoomba, Qld, Australia)

Böckl, M, Blay, K, Fischer, K, Mommertz, S, Filser, J (1998). Colonisation of a copper-decontaminated soil by micro- and mesofauna. *Applied Soil Ecology* **9(1-3 Special Issue SI)**, 489-494.

Bogomolov, DM, Chen, SK, Parmelee, RW, Subler, S, Edwards, CA (1996). An ecosystem approach to soil toxicity testing: a study of copper contamination in laboratory soil microcosms. *Applied Soil Ecology* **4(2)**, 95-105.

Bordallo, JJ, Lopez Llorca, LV, Jansson, HB, Salinas, J, Persmark, L, Asensio, L (2002). Colonization of plant roots by egg-parasitic and nematode-trapping fungi. *New Phytologist* **154(2)**, 491-499.

Boulter, JI, Boland, GJ, Trevors, JT (2002). Evaluation of composts for suppression of dollar spot (Sclerotinia homoeocarpa) of turfgrass. *Plant Disease* **86(4)**, 405-410.

Brimner, TA, Boland, GJ (2003). A review of the non-target effects of fungi used to biologically control plant diseases. *Agriculture, Ecosystems and Environment* **100(1)**, 3-16.

Brinton, W, Droffnew, M (1995). The control of plant pathogenic fungi by use of compost teas. *Biodynamics* **197**, 12-16.

Brinton, WF, Trankner, A, Droffner, M (1996). Investigations into liquid compost extracts. *BioCycle* **37(11)**, 68-70.

Brun, LA, Maillet, J, Richarte, J, Herrmann, P, Remy, JC (1998). Relationships between Extractable Copper, Soil Properties and Copper Uptake by Wild Plants in Vineyard Soils. *Environmental Pollution* **102(2-3)**, 151-161.

Carisse, O, Bernier, J, Benhamou, N (2003). Selection of biological agents from composts for control of damping-off of cucumber caused by Pythium ultimum. *Canadian Journal of Plant Pathology* **25(3)**, 258-267.

Carisse, O, Ouimet, A, Toussaint, V, Philion, V (2000). Evaluation of the effect of seed treatments, bactericides, and cultivars on bacterial leaf spot of lettuce caused by Xanthomonas campestris pv. vitians. *Plant Disease* **84(3)**, 295-299.

Chaignon, V, Sanchez Neira, I, Herrmann, P, Jaillard, B, Hinsinger, P (2003). Copper bioavailability and extractability as related to chemical properties of contaminated soils from a vine-growing area. *Environmental Pollution* **123(2)**, 229-238.

Chalker-Scott L. (2003). The myth of compost tea revisited: Aerobically-brewed compost tea suppresses disease. **www.cfr.washington.edu/research.mulch/**.

Chardonnet, C, Hyvernay, AL, Doneche, B (1997). Effect of calcium treatment prior to *Botrytis cinerea* infection on the changes in pectic composisition of grape berry. *Physiological and Molecular Plant Pathology* **50**, 213-218.

Chen, WD, Hoitink, HAJ, Schmitthenner, AF, Tuovinen, OH (1988). The role of microbial acitivity in suppression of damping-off caused by Pythium ultimum. *Phytopathology* **78(3)**, 314-322.

Coates L, Johnson G (1997). Postharvest diseases of fruit and vegetables. In 'Plant Pathogens and Plant Diseases'. pp. 533-547. (Rockvale Publications: Armidale, NSW.)

Conway, KE, Maness, NE, Motes, JE (1997). Integration of biological and chemical controls for Rhizoctonia aerial blight and root rot of rosemary. *Plant Disease* **81(7)**, 795-798.

Conway, WS, Sams, CE (1984). Possible mechanisms by which postharvest calcium treatment reduces decay in apples. *Phytopathology* **74**, 208-210.

Cook RJ, Baker KF (1996) 'The nature and practice of biological control of plant pathogens.' (APS Press, The American Phytopathological Society: St. Paul, Minnesota)

Copper Development Association (1948) 'Copper compounds in agriculture and industrial microbiology.' (Copper Development Association: London, Great Britain)

Copper Development Association (2003). Uses of copper compounds. **www.copper.org/applications/compounds/copper_sulfate02.html**.

Cotxarrera, L, Trillas Gay, MI, Steinberg, C, Alabouvette, C (2002). Use of sewage sludge compost and Trichoderma asperellum isolates to suppress Fusarium wilt of tomato. *Soil Biology and Biochemistry* **34(4)**, 467-476.

Crisp, P (2002). Drop of white the right stuff for vines. **www.adelaide.edu.au/pr/media/releases/2002/milkwine.html**.

Crisp P, Scott E, Wicks T (2002) Novel control of grapevine powdery mildew, *Uncinula necator*. In 'Proceedings of Fourth International Workshop on Powdery and Downy Mildew in Grapevine. Napa California, USA, 30 September - 4 October 2002. Eds. Gadoury, DM Department of Plant Pathology, University of California, USA p78.'.

Croplife (2002). A history of crop protection and pest control in our society. In 'Analyzing the risks, balancing the bevefits: the facts on pesticides and human safety'. (www.croplife.ca/english/pdf/Analyzing2003/T1History.pdf:

Currie, CR (1995). Dissemination of the mycoparasite Scytalidium uredinicola by Epuraea obliquus (Coleoptera: Nitidulidae). *Canadian Journal of Botany* **73(9)**, 1338-1344.

da Tatagiba, JS, Maffia, LA, Barreto, RW, Alfenas, AC, Sutton, JC (1998). Biological control of Botrytis cinerea in residues and flowers of rose (Rosa hybrida). *Phytoparasitica* **26(1)**, 8-19.

Daayf, F, Schmitt, A, Belanger, RR (1995). The effects of plant extracts of Reynoutria sachalinensis on powdery mildew development and leaf physiology of long English cucumber. *Plant Disease* **79(6)**, 577-580.

Daoust, RA, Hofstein, R (1996). *Ampelomyces quisqualis,* a new biofungicide to control powdery mildew in grapes. *Brighton Crop Protection Conference: Pests and Diseases - 1996. Proceedings of an International Conference, Brighton, UK, 18-21 November, 1996.* **1**, 33-40.

Darvas, JM (1982). Chemical control of Cercospora spot disease of avocados. *Yearbook,-South-African-Avocado-Growers'-Association. 1982, 5: 58-59; 4 ref* .

Darvas, JM (1983a). Control of Cercospora spot in the 1981/82 season. *Yearbook,-South-African-Avocado-Growers'-Association. 1983, 6: 54-55; 6 ref* .

Darvas, JM (1983b). Pre-harvest chemical control of post-harvest avocado diseases in the 1981/82 season. *Yearbook,-South-African-Avocado-Growers'-Association. 1983, 6: 48-49; 5 ref* .

Darvas, JM, Kotze, JM, Wehner, FC (1987). Field occurrence and control of fungi causing postharvest decay of avocados. *Phytophylactica* **19(4)**, 453-455; 15 ref.

Datar, VV, Shinde, NN, Gadambe, DV (1992). Management of root rot of eggplant (Solanum melongena L.) caused by Sclerotium rolfsii Sacc. *Maharashtra Journal of Horticulture* **6(1)**, 51-55.

David S (2001) 'Identification of techniques to produce poultry manure and compost-tea and their benefits in vegetation production.' (Horticultural Research and Development Corporation, Sydney, Australia)

de Bruyn, LAL (1997). The status of soil macrofauna as indicators of soil health to monitor the sustainability of Australian agricultural soils. *Ecological Economics* **23(2)**, 167-178.

de Villiers, EE, Korsten, L (1996). Alternative strategies for control of mango fruit diseases. *Yearbook South African Mango Growers' Association* **16**, 61-64.

de Vrije, T, Antoine, N, Buitelaar, RM, Bruckner, S, Dissevelt, M, Durand, A, Gerlagh, M, Jones, EE, Luth, P, Oostra, J, Ravensberg, WJ, Renaud, R, Rinzema, A, Weber, FJ, Whipps, JM (2001). The fungal biocontrol agent Coniothyrium minitans: production by solid-state fermentation, application and marketing. *Applied Microbiology and Biotechnology* **56(1-2)**, 58-68.

de Wet, TH (1982). Bacterial spot and blossom malformation. *Research-Report, South African Mango Growers' Association* **2**, 18-22.

Deacon, JW (1973). Factors affecting occurrence of the Ophiobolus patch disease of turf and its control by Phialophora radicicola. *Plant Pathology* **22(4)**, 149-155.

Demir S, Gul A, Onogur E, Tuzel Y (ed.), Burrage SW (ed.), Bailey BJ (ed.), Gul A (ed.), Smith AR (ed.), Tuncay O (1999). The effect of sodium bicarbonate on powdery mildew in tomato. *Proceedings of the international symposium on greenhouse management for better yield and quality in mild winter climates, Antalya, Turkey, 3-5 November, 1997. Acta-Horticulturae. 1999, No. 491, 449-452; 16 ref* .

Develash, RK, Sugha, SK (1997). Management of downy mildew (Peronospora destructor) of onion (Allium cepa). *Crop Protection* **16(1)**, 63-67.

Downer, J, Faber, B, Menge, J (2002). Factors affecting root rot control in mulched avocado orchards. *Proceedings of the workshop 'Pest management during transition from conventional to organic farming', presented at ASHS 2001, Sacramento, California, USA, 22 25 July, 2002* **12(4)**, 601-605.

Dumestre, A, Sauve, S, McBride, M, Baveye, P, Berthelin, J (1999). Copper speciation and microbial activity in long-term contaminated soils. *Archives of Environmental Contamination & Toxicology.* **36(2)**, 124-131.

Dutta, P, Das, BC (2002). Management of collar rot of tomato by Trichoderma spp. and chemicals. *Indian Phytopathology* **55(2)**, 235-237.

Eckert, JW, Sommer, NF (1967). Control of diseases of fruits and vegetatbles by posthavest treatment. *Annual Review of Phytopathology* **5**, 391-432.

Eden, MA, Hill, RA, Stewart, A (1996). Biological control of Botrytis stem infection of greenhouse tomatoes. *Plant Pathology* **45(2)**, 276-284.

Elad, Y (1997). Responses of plants to infection by *Botrytis cinerea* and novel means involved in reducing their susceptibility to infection. *Biological Reviews* **72**, 381-422.

Elad, Y (2000). Trichoderma harzianum T39 preparation for biocontrol of plant diseases - control of Botrytis cinerea, Sclerotinia sclerotiorum and Cladosporium fulvum. *Biocontrol Science and Technology* **10(4)**, 499-507.

Elad, Y, Volpin, H (1988). The involvement of ethylene and calcium in gray mould of pelargonium, ruscus, and rose plants. *Phytoparasitica* **16**, 119-131.

Enkelmann, R, Wohlfarth, P (1994). Aluminium residues on and in grapes as well as in must and wine after application of Ulmasud. *Angewandte Botanik* **68(5-6)**, 187-190.

Fahima, T, Wu, Y, Zhang, L, Van Alfen, K (1994). Identification of the putative RNA polymerase of Cryphonectria hypovirus in a solubilized replication complex. *Journal of Virology* **68(9)**, 6116-6119.

Faize, M, Brisset, MN, Paulin, JP, Tharaud, M (1999). Secretion and regulation Hrp mutants of Erwinia amylovora trigger different responses in apple. *FEMS Microbiology Letters* **171(2)**, 173-178.

Falk, SP, Gadoury, DM, Cortesi, P, Pearson, RC, Seem, RC (1995a). Parasitism of Uncinula necator cleistothecia by the mycoparasite Ampelomyces quisqualis. *Phytopathology* **85(7)**, 794-800.

Falk, SP, Gadoury, DM, Pearson, RC, Seem, RC (1995b). Partial control of grape powdery mildew by the mycoparasite Ampelomyces quisqualis. *Plant Disease* **79(5)**, 483-490.

Ferguson, IB (1984). Calcium in plant senescence and fruit ripening. *Plant, Cell and Environment* **7**, 477-489.

Filion, M, St-Arnaud, M, Fortin, JA (1999). Direct interaction between the arbuscular mycorrhizal fungus glomus intraradices and different rhizosphere microorganisms. *New Phytologist. 1999. 141: 3, 525-533. 62 ref.* **141(3)**, 525-533.

Fitzell RD (1994) 'Diseases and disorders of macadamias.' (NSW Agriculture, Wollongbar Agricultural Institute: Wollongbar)

Floyd, R (1991). Bordeaux mixture and similar copper fungicides. *Farmnote* **78/1991**.

Frank, E, Pansy, FE, Pagano, JF (1959). Nystatin in the control of fingal infections of orchids. *Antibiotics Annual* , 898-902.

Gaikwad, AP, Salunkhe, GN, Nimbalkar, CA (2002). Efficacy of fungicides against fruit rot of custard apple. *Journal of Maharashtra Agricultural Universities* **27(1)**, 70-72.

Gallagher, DL, Johnston, KM, Dietrich, AM (2001). Fate and transport of copper-based crop protectants in plasticulture runoff and the impact of sedimentation as a best management practice. *Water Research.* **35(12)**, 2984-2994.

Garcia, C, Pascual, JA, Mena, E, Hernandez, T Influence of the stabilisation of organic materials on their biopesticide effect in soils. *Bioresource Technology* **In Press, Corrected Proof**.

Gracia Garza, JA, Little, M, Brown, W, Blom, TJ, Schneider, K, Allen, W, Potter, J (2003). Efficacy of various biological control agents and biorationals against Pythium root rot in poinsettia. *HortTechnology* **13(1)**, 149-153.

Graham, JH, Timmer, LW, Fardelmann, D (1986). Toxicity of fungicidal copper in soil to citrus seedlings and vesicular-arbuscular mycorrhizal fungi. *Phytopathology* **76(1)**, 66-70.

Grobe, K (1997). It's a new era for farm compost. *BioCycle. 1997, 38: 5, 52-54* **38(5)**, 52-54.

Gullino, ML, Monchiero, M, Garibaldi, A (1984). Observations on the effect of copper products on downy mildew and grey mould of grapevine in Piedmont. *Vignevini* **11(5)**, 63-65.

Gullino, ML, Morando, A (1984). Copper fungicides: traditional products used with success in modern viticulture. *Vignevini* **11(1-2)**, 35-37.

Gupta, JH (1992). Chemical control of algal rust of litchi caused by Cephaleuros virescens Kunze. *Progressive Horticulture* **24(1-2)**, 109-110.

Hammer, PE, Evensen, KB, Janisiewicz, WJ (1993). Postharvest control of *Botrytis cinerea* on cut rose flowers with pyrrolnitrin. *Plant Disease* **77**, 283-286.

Hansen, M (2001). Worming a farm to success. *Australian Farm Journal* **(January)**, 28-30.

Hanson, AD, Kende, H (1975). Ethylene-induced ion and sucros efflux in morning glory flower tissue. *Plant Phsiology* **55**, 663-669.

Harrison, JG (1988). The biology of *Botrytis* spp. on *Vicia* beans and chocolate spot disease - a review. *Plant Pathology* **37**, 168-201.

Helling, B, Reineeke, SA, Reineeke, AJ (2000). Effects of the fungicide copper oxychloride on the growth and reproduction of Eisenia fetida (Oligochaeta). *Ecotoxicology and Environmental Safety, Environmental Research, Section B* **46(1)**, 108-116.

Herger, G, Klingauf, F (1990). Control of powdery mildew fungi with extracts of the giant knotweed, Reynoutria sachalinensis (Polygonaceae). *Mededelingen van de Faculteit Landbouwwetenschappen, Rijksuniversiteit Gent* **55(3a)**, 1007-1014.

Hirst, JM, Storey, IF, Ward, WC, Wilcox, HG (1995). The origin of apple scab epidemics in the Wisbech area in 1953 and 1954. *Plant Pathology* **4**, 91-95.

Hofmann, U (1996). Control of downy mildew in organic grape production. *Obstbau-Weinbau* **33(4)**, 105-107.

Hofstein, R, Daoust, RA, Aeschlimann, JP (1996). Constraints to the development of biofungicides: the example of "AQ10", a new product for controlling powdery mildews. *Entomophaga* **41(3-4)**, 455-460.

Hoitink, HAJ, Boehm, MJ (1999). Biocontrol within the context of soil microbial communities: a substrate-dependent phenomenon. *Annual Review of Phytopathology* **37**, 427-446.

Htay, K, Kerr, A (1974). Biological control of crown gall: seed and root inoculation. *Journal of Applied Bacteriology* **37(4)**, 525-530.

Huang, HC, Bremer, E, Hynes, RK, Erickson, RS (2000). Foliar application of fungal biocontrol agents for the control of white mold of dry bean caused by Sclerotinia sclerotiorum. *Biological Control* **18(3)**, 270-276.

Huq, MI, Ahmed, HU, Malaker, PK (1994). Control of sigatoka of banana with foliar fungicides. *Bangladesh Journal of Scientific and Industrial Research* **29(2)**, 81-85.

Hussaini, SH, Singh, H (1989). Efficacy of different fungicides against Alternaria blight of radish seed crop. *Plant Disease Research* **4(2)**, 105-107.

Irish, BM, Correll, JC, Morelock, TE (2002). The effect of synthetic surfactants on disease severity of white rust on spinach. *Plant Disease* **86(7)**, 791-796.

Janisiewicz, WJ, Jeffers, SN (1997). Efficacy of commercial formulation of two biofungicides for control of blue mold and gray mold of apples in cold storage. *Crop Protection* **16(7)**, 629-633.

Jaworska, M, Gorczyca, A (2002). The effect of metal ions on mortality, pathogenicity and reproduction of entomopathogenic nematodes Steinernema feltiae Filipjev (Rhabditida, Steinernematidae). *Polish Journal of Environmental Studies* **11(5)**, 517-519.

Johansson, JF, Paul, LR, Finlay, RD (2004). Microbial interactions in the mycorrhizosphere and their significance for sustainable agriculture. *FEMS Microbiology Ecology* **48(1)**, 1-13.

Jollands, P, Jollands, P, George, S (1989). Fungicide deposition studies in the control of black pod disease of cocoa in Papua New Guinea. *Crop Protection* **8(2)**, 91-97.

Jones, EE, Whipps, JM (2002). Effect of inoculum rates and sources of Coniothyrium minitans on control of Sclerotinia sclerotiorum disease in glasshouse lettuce. *European Journal of Plant Pathology* **108(6)**, 527-538.

Joyce, DC, Johnson, GI (1999). Prospects for exploitation of natural disease resistance in harvested horticultural crops. *Posthavest News and Information* **10**, 45N-48N.

Kaile, A, Pitt, D, Kuhn, PJ (1991). Release of calcium and other ions from various plant host tissues infected by different necrotrophic pathogens with special reference to *Botrytis cinerea* Pers. *Phytiological and Molecular Plant Pathology* **38**, 275-291.

Kaile, A, Pitt, D, Kuhn, PJ (1992). Calcium cytotoxicity, protoplast viability and the role of calcium in soft-rot of *Brassica napus* due to *Botrytis cinerea* Pers. *Phsiological and Molecular Plant Pathology* **40**, 49-62.

Kessman, H, Staub, T, Hofman, C, Maetzke, T, Herzog, J, Ward, E, Uknes, S, Ryals, J (1994). Induction of systemic acquired disease resistance in plants by chemicals. *Annual Review of Phytopathology* **32**, 439-459.

Kilic, O, Griffin, GJ (1998). Effect of dsRNA-containing and dsRNA-free hypovirulent isolates of Fusarium oxysporum on severity of fusarium seedling disease of soybean in naturally infested soil. *Plant and Soil* **201(1)**, 125-135.

Knudsen, IMB, Debosz, K, Hockenhull, J, Jensen, DF, Elmholt, S (1999). Suppressiveness of organically and conventionally managed soils towards brown foot rot of barley. *Applied Soil Ecology* **12(1)**, 61-72.

Kong, FX (1995). Influence of copper, manganese and pH on the growth and several enzyme activities in mycorrhizal fungus Amanita muscaria. *Chemosphere* **30(1)**, 199-207.

Korsten, L, Villiers, EE de, Duvenhage, JA, Kotze, JM, De Villiers, EE (1994). Control of avocado pre-harvest diseases with Bacillus subtilis and fungicide sprays. *Yearbook South African Avocado Growers' Association* **17**, 32-34.

Korsten, L, Villiers, EE de, Rowell, A, Kotze, JM, De Villiers, EE (1993). Postharvest biological control of avocado fruit diseases. *Yearbook South African Avocado Growers' Association* **16**, 65-69.

Kotze, JM, du Toit, FL, Durand, SJ (1982). Pre-harvest chemical control of anthracnose, sooty blotch and Cercospora spot of avocados. *Yearbook,-South-African-Avocado-Growers'-Association. 1982, 5: 54-55; 2 tab.; 6 ref* .

Kotze, JM, Kuschke, E, Durand, B (1981). Pre-harvest chemical control of anthracnose and sooty blotch. *Yearbook,-South-African-Avocado-Growers'-Association. 1981, 4: 69-70; 2 ref* .

Kuepper, G, Thomas, R, Earler, R (2001). Use of Baking Soda as a fungicide. *Appropriate Technology Transfer for Rural Areas (ATTRA) Horticulture Technical Note* .

Kuhlman, EG (1981). Parasite interaction with sporulation by Cronartium quercuum f. sp. fusiforme on loblolly and slash pine. *Phytopathology* **71(3)**, 348-350.

Kula, H, Larink, O, Edwards, CA (1997). Development and standardization of test methods for the prediction of sublethal effects of chemicals on earthworms. *5th International symposium on earthworm ecology held in Columbus, Ohio, USA, 5 9 July 1994* **29(3-4)**, 635-639.

Labuschagne, N, Rowell, AWG (1983). Chemical control of post-harvest diseases of avocados by pre-harvest fungicide application. *Yearbook,-South-African-Avocado-Growers'-Association. 1983, 6: 46-47; 1 ref* .

Lameri P, Paci F, Brunelli Aed, Canova A (2002). Fitoil(R) a new natural adjuvant on based soybean oil for copper salts: results of two years trials in grapevine and tomato. In 'Atti,-Giornate-fitopatologiche,-Baselga-di-Pine,-Trento,-Italy,-7-11-aprile-2002,-Volume-2. 2002, 151-158; 12 ref'.

Larena, P, Sabuquillo, P, Melgarejo, P, de Cal, A (2003). Biocontrol of fusarium and verticillium wilt of tomato by Penicillium oxalicum under greenhouse and field conditions. *Journal of Phytopathology* **151(9)**, 507-512.

Lee KE (1985) 'Earthworm: Their ecology and relationships with soils and land use.' (Academic Press: Australia)

Lepp NW, Dickinson NM, Ross SM (1994). Fungicide-derived copper in tropical plantation crops. In 'Toxic-metals-in-soil-plant-systems.'. pp. 367-393.

Letham, DB, Stovold, GE (1995). Fungicide properties and uses. *Agfacts* **Agdex 683**.

Liao, JP, Lin, XG, Cao, ZH, Shi, YQ, Wong, MH (2003). Interactions between arbuscular mycorrhizae and heavy metals under sand culture experiment. *Chemosphere* **50(6)**, 847-853.

Lonsdale JH (1991). Control of preharvest fruit diseases of avocado. Part 1: efficacy of various triazole fungicides against Cercospora spot and sooty blotch. *Yearbook -South-African-Avocado-Growers'-Association* **14**, 61-62.

Lumsden, RD, Lewis, JA, Millner, PD (1986). Effect of composted sewage sludge on several soilborne plant pathogens and diseases. *Phytopathology* **73**, 1543-1548.

Ma, W (1984). Sublethal toxic effects of copper on growth, reproduction and litter breakdown activity in the earthworm Lumbricus rubellus, with observations on the influence of temperature and soil pH. *Environmental Pollution, A* **33(3)**, 207-219.

Ma, W, Edelman, T, Beersum, I Van, Jans, T (1983). Uptake of cadmium, zinc, lead, and copper by earthworms near a zinc-smelting complex: influence of soil pH and organic matter. *Bulletin of Environmental Contamination and Toxicology* **30(4)**, 424-427.

Mabbett, TH, Phelps, RH The behavior of copper deposits from low and ultralow volume sprays on tomato foliage and their control of early blight. *Thai-Journal-of-Agricultural-Science. 1985, 18: 2, 81-100* .

Maboeta, MS, Reinecke, SA, Reinecke, AJ (2003). Linking lysosomal biomarker and population responses in a field population of Aporrectodea caliginosa (Oligochaeta) exposed to the fungicide copper oxychloride. *Ecotoxicology and Environmental Safety* **56(3)**, 411-418.

Maccagnani, B, Mocioni, M, Gullino, ML, Ladurner, E, van Lenteren, JC (1999). Application of Trichoderma harzianum by using Apis mellifera as a vector for the control of grey mould of strawberry: first results. *IOBC WPRS Working Group "Integrated Control in Glasshouses". Proceedings of the meeting at Brest. France, 25-29 May, 1999. Bulletin-OILB-SROP* **. 22(1)**, 161-164.

Madi, L, Katan, T, Katan, J, Henis, Y (1997). Biological control of Sclerotium rolfsii and Verticillium dahliae by Talaromyces flavus is mediated by different mechanisms. *Phytopathology* **87(10)**, 1054-1060.

Makeschin F (1997). Earthworms (*Lumbricidae*: *Oligochaeta*): Important promoters of soil development and soil fertility. In 'Fauna in Soil Ecosystems. Recycling Processes, Nutrient Fluxes and Agricultural Production.'. (Ed. G Benckiser) pp. 172-223. (Marcel Dekker Inc: New York)

Mansfield, JW, Deverall, BJ (1974). The rates of fungal development and lesion formation in leaves of *Vicia faba* during infection by *Botrytis cinerea* and *Botrytis fabae*. *Annals of Applied Biology* **76**, 77-89.

Mao, W, Lewis, JA, Lumsden, RD, Hebbar, KP (1998). Biocontrol of selected soilborne diseases of tomato and pepper plants. *Crop Protection* **17(6)**, 535-542.

Marinescu, G (1980). Research on certain biological aspects and control of the bacterium that produces leaf spot and soft rot of cucumber fruits. *Bulletin-de-l'Academie-des-Sciences-Agricoles-et-Forestieres.* **10**, 103-108.

Marschner H (1995) 'Mineral Nutrition in Higher Plants.' (Academic Press Ltd: London)

Martin, JT (1964). Role of cuticle in the defense against plant disease. *Annual Review of Phytopathology* **2**, 81-100.

Mathivanan, N, Srinivasan, K, Chelliah, S (2000). Biological control of soil-borne diseases of cotton, eggplant, okra and sunflower by Trichoderma viride. *Zeitschrift fur Pflanzenkrankheiten und Pflanzenschutz* **107(3)**, 235-244.

Mayak, S, Vaadia, Y, Dilley, DR (1977). Regulation of senescence in carnation (*Dianthus caryuphyllus*) by ethylene. *Plant Physiology* **59**, 591-593.

McCain, AH (1983). Leaf curl fungicides. *California-Plant-Pathology*. **64**, 1-2.

McCoy, CW, Lye BenHuai, Lye, BH (1996). Effect of copper sprays on the population dynamics of the citrus rust mite, Phyllocoptruta oleivora (Acari: Eriophyidae) and its fungal pathogen, Hirsutella thompsonii. *Proceedings-of-the-Florida-State-Horticultural-Society. 1995, publ. 1996, No. 108, 126-129; 22 ref* .

McMillan, RT (1973). Control of anthracnose and powdery mildew of mango with systemic and non-systemic fungicides. *Tropical Agriculture* **50(3)**, 245-248.

McQuilken, MP, Whipps, JM, Cooke, RC (1990). Control of damping-off in cress and sugar-beet by commercial seed-coating with Pythium oligandrum. *Plant Pathology* **39(3)**, 452-462.

Merrill R, McKeon J (1998) 'Organic teas from compost and manures.' (Organic Farming Research Foundation, Santa Cruz, California)

Merrington, G, Rogers, SL, van Zwieten, L (2002). The potential impact of long-term copper fungicide usage on soil microbial biomass and microbial activity in an avocado orchard. *Australian-Journal-of-Soil-Research* **40(5)**, 749-759; many ref.

Merry, RH, Tiller, KG, Alston, AM (1983). Accumulation of copper, lead and arsenic in some Australian orchard soils. *Australian Journal of Soil Research* **21(4)**, 549-561.

Michaud, JP, Grant, AK (2003). Sub-lethal effects of a copper sulfate fungicide on development and reproduction in three coccinellid species. *Journal of Insect Science* **3(16)**, 1-6.

Mickler, CJ, Adaskaveg, JE, Stanghellini, ME (1998). Evaluation of a soil surfactant for control of Phytophthora root rot of citrus. *Phytopathology* **88(S42)**.

Mischke, S (1998). Mycoparasitism of selected sclerotia-forming fungi by Sporidesmium sclerotivorum. *Canadian Journal of Botany* **76(3)**, 460-466.

Moorman, GW, Lease, RJ (1992). Residual efficacy of fungicides used in the management of Botrytis cinerea on greenhouse-grown geraniums. *Plant Disease* **76(4)**, 374-376.

Morgan, JE, Morgan, AJ (1988). Earthworms as biological monitors of cadmium, copper, lead and zinc in metalliferous soils. *Environmental Pollution* **54(2)**, 123-138.

Morris, RAC, Royle, DJ, Whelan, MJ, Arnold, GM Biocontrol of willow rusts with the hyperparasite Sphaerellopsis filum. *Brighton Crop Protection Conference, Pests and Diseases - 1994. Volume 3. 1994, 1121-1126; 9 ref* .

Mount, MS, Bermnan, PM (1994). Genetic manipulation of plants to improve postharvest disease resistance. *HortScience* **29**, 762-768.

Nambiar, KKN, Rethinam, P, Mani Varghese, Varghese, M (1992). Management of Ganoderma wilt disease of coconut in Kerala. *Indian Coconut Journal Cochin* **22(10)**, 6-9.

Neeson R (2001) Organic agriculture soil health strategies. In 'Soil Health: The foundation of sustainable agriculture.'. Wollongbar Agricultural Institute. (Ed. R Lines-Kelly) (NSW Agriculture:

Nicholson, FA, Smith, SR, Alloway, BJ, Carlton-Smith, C, Chambers, BJ (2003). An inventory of heavy metals inputs to agricultural soils in England and Wales. *The Science of The Total Environment* **311(1-3)**, 205-219.

Niemi, M, Lahdenpera, ML (2000). *Gliocladium catenulatum* J1446 - a new biofungicide for horticultural crops. *17th Danish Plant Protection Conference, Horticulture. DJF Rapport, Havebrug, 2000* **12**, 81-88.

NSW Agriculture (1994) (NSW Agriculture: Sydney)

O'Hare P, Vock N (1990) 'Growing macadamias in Queensland.' (Queensland Department of Primary Industries: Nambour, Qld)

Obagwu, J, Korsten, L (2003). Integrated control of citrus green and blue molds using Bacillus subtilis in combination with sodium bicarbonate or hot water. *Postharvest Biology and Technology* **28(1)**, 187-194.

Olkowski W, Daar S, Olkowski H (1991) 'Commonsense pest control.' (Taunton Press: Newtown, CT)

Paoletti, MG, Sommaggio, D, Favretto, MR, Petruzzelli, G, Pezzarossa, B, Barbafieri, M (1998). Earthworms as useful bioindicators of agroecosystem sustainability in orchards and vineyards with different inputs. *Applied Soil Ecology* **10(1-2)**, 137-150.

Parlevliet G, McCoy S (2001) 'Organic grapes and wine: A guide to production.' (Rural Industries Research and Development Corporation, Bulletin 4516, Department of Agriculture, Western Australia)

Pasini, C, d'Aquila, F, Curir, P, Gullino, ML, Albajes, R, Carnero, A (1997). Alternative strategies to control rose powdery mildew. *Integrated control in protected crops 'Mediterranean climate'. Proceedings of the meeting at Tenerife, Canary Islands, 3 - 6 November 1997. Bulletin-OILB-SROP* **20(4)**, 84-87.

Patil, RS, Deshpande, AM, Natu, AA, Nahar, P, Chitnis, M, Ghormade, V, Laxman, RS, Rokade, S, Deshpande, MV (2001). Biocontrol of root infecting plant pathogenic fungus, Sclerotium rolfsii using mycolytic enzymes and chitin metabolism inhibitors singly and in combination. *Journal of Biological Control* **15(2)**, 157-164.

Peot, C, McIntyre, O (2000). Generating revenue from compost facility runoff. *BioCycle* **41(6)**, 34-36.

Persson, C, Jansson, HB (1999). Rhizosphere colonization and control of Meloidogyne spp. by nematode-trapping fungi. *Journal of Nematology* **31(2)**, 164-171.

Peterson, PD, Griffith, CS, Campbell, CL (1995). Treatment of grape diseases: the science and successes of Frank Lamson-Scribner. *Plant Disease* **79(1)**, 89-94.

Peterson, RA, Inch, AJ (1980). Control of anthracnose on avocados in Queensland. *Queensland-Journal-of-Agricultural-and-Animal-Sciences* **37(1)**, 79-83; 1 pl.; 9 ref.

Plagge, J, Rommelt, S (1997). Study on the effect of alternative control methods against blossom infection with fireblight (Erwinia amylovora) in apples. *Contributions to the 4th Scientific Meeting on Ecological Agriculture, held on 3 4 March 1997, at the Rheinische Friedrich Wilhelms Universitat Bonn* **4**, 199-203.

Poovaiah, BW (1986). Role of calcium in prolonging storage life of fruits and vegetables. *Food*

Technology **40**, 86-89.

Postma, J, Montanari, M, van den Boogert, PHJF, Insam, Hed, Garcia, Ced, Garland, JL (2003). Microbial enrichment to enhance the disease suppressive activity of compost. *European Journal of Soil Biology* **39(3)**, 157-163.

Prakasam, V, Subbaraja, KT (1994). Manage heart-rot of pineapple. *Indian-Horticulture* **39(1)**, 14.

Prasad, RD, Rangeshwaran, R, Hegde, SV, Anuroop, CP (2002a). Effect of soil and seed application of trichoderma harzianum on pigeonpea wilt caused by fusarium udum under field conditions. *Crop Protection* **21(4)**, 293-297.

Prasad, RD, Rangeshwaran, R, Sunanda, CR, Vinita, J (2002b). Biological control of black spot of rose caused by Diplocarpon rosae. *Annals of Plant Protection Sciences* **10(2)**, 256-259.

Pratella, GC, Mari, M (1993). Effectiveness of Trichoderma, Gliocladium and Paecilomyces in postharvest fruit protection*1. *Postharvest Biology and Technology* **3(1)**, 49-56.

Pratt, JE (1997). Fomes stump treatment - an update. *Quarterly Journal of Forestry* **91(1)**, 63-65.

Pratt, JE, Gibbs, JN, Webber, JF (1999). Registration of Phlebiopsis gigantea as a forest biocontrol agent in the UK: recent experience. *Biocontrol Science and Technology* **9(1)**, 113-118.

Rabbidge J, Fan G (2004) Ecological risk assessment of agricultural, veterinary and industrial chemicals in Australia by the Department of the Environment and Heritage. In 'Contaminants and Ecological Risk Assessment Workshop'. 5-7 April 2004, Adelaide, South Australia. p. 53. (CSIRO Land and Water: Glen Osmond, South Australia)

Rawal, RD, Ullasa, BA (1988). Management of fruit diseases of guava (Psidium guajava) through fungicidal sprays. *Indian Journal of Agricultural Sciences* **58(12)**, 950-952.

Ray, J (1901). Les maladies cryptogamiques des végétaux. *Review of General Botamny* **13**, 145-151.

Reddi, MS, Pandu, SR, Rao, AA (1987). Mechanism of acquired resistance of fungi to fungicides. *Indian Phytopathology* **40(2)**, 258-261.

Reddy, MK, Mohan, RC (1984). Effect of certain fungicides on Phytophthora palmivora of cocoa. *Pesticides* **18(1)**, 51-53.

Reuveni, R, Raviv, M, Krasnovsky, A, Freiman, L, Medina, S, Bar, A, Orion, D (2002). Compost induces protection against Fusarium oxysporum in sweet basil. *Crop Protection* **21(7)**, 583-587.

Rommelt, S, Plagge, J, Treutter, D, Zeller, W (1999). Fire blight control in apple using alternative products. *Gesunde Pflanzen* **51(3)**, 72-74.

Rossall, S, Mansfield, JW (1981). Nutrients and lesion formation by *Botrytis cinerea* on leaves of *Vicia faba*. *Transactions of the British Mycological Society* **76**, 172-175.

Ruiz, RAR, Alfenas, AC, Demuner, NL (1991). Efficiency of fungicides for the control of rust (Puccinia psidii) on guava (Psidium guajava). *Summa Phytopathologica* **17(2)**, 147-153.

Ryals, J, Uknes, S, Ward, E (1994). Systemic acquired resistance. *Plant Physiology* **104**, 1109-1112.

Sabehat, A, Zieslin, N (1994). GA_3 effects on postharvest alteations in cell membranes of rose (*Rosa* x *Hybrida*) petals. *Journal of Plant Physiology*. **144**, 513-517.

Salminen, J, Haimi, J (2001). Life history and spatial distribution of the enchytraeid worm Cognettia sphagnetorum (Oligochaeta) in metal-polluted soil: below-ground sink-source population dynamics? *Environmental Toxicology and Chemistry* **20(9)**, 1993-1999.

Sances, FV, Ingham, ER Conventional and organic alternatives to methyl bromide on California strawberries. *Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, San Diego, California, USA, 1-4 November, 1999. 1999, 3 pp.; Available on the internet at http:-search.epa.gov-spdpublc-mbr-mbrqa.html* .

Sanders, GM, Korsten, L, Wehner, FC (2000). Survey of fungicide sensitivity in Colletotrichum gloeosporioides from different avocado and mango production areas in South Africa. *European-Journal-of-Plant-Pathology* **106(8)**, 745-752; 38 ref.

Scarpa, R, Spalatro, F (2001). Consumer's preference heterogeneity: the case of organic and integrated pest-management in table grapes and strawberries. *Rivista di Economia Agraria* **56(3)**, 417-450.

Scheuerell, S, Mahaffee, W (2002). Compost tea: principles and prospects for plant disease control. *Compost-Science-and-Utilization* **10(4)**, 313-338; many ref.

Schilder AMC, Gillett JM, Sysak RW, Wise JC, Fordergemeinschaft Okologischer Obstbau e V Evaluation of environmentally friendly products for control of fungal diseases of grapes. In '10th-International-Conference-on-Cultivation-Technique-and-Phytopathological-Problems-in-Organic-Fruit-Growing-and-Viticulture.-Proceedings-of-a-conference,-Weinsberg,-Germany,-4-7-February-2002. 2002, 163-167; 2 ref'.

Schmitt A, Kunz S, Nandi S, Seddon B, Ernst A (2002) Use of *Reynoutria sachalinensis* plant extracts, clay preparations and *Brevibacillus brevis* against fungal diseases of grape berries. In 'Proceedings of the 10th International Conference on Cultivation Technique and Phytopathological Problems in Organic Fruit Growing and Viticulture, 4-7 February 2002. Weinsberg, Germany. pp 146-151'.

Schneiderhan, FJ (1933). The discorvery of Bordeaux mixture: Three papers: I. Treatment of mildew and rot./ II. Treatement of mildew with copper sulphate and lime mixture./ III. Concerning the history of the treatment of mildew with copper sulphate. By Perre Marie Alexis Millardet 1885. A Translation from the French by Felix John Schneiderhan. American Phytopathological Society. *Phytopathological Classics* **3**.

Schuld M, White D, Seddon B, Ernst A, Schmitt A (2002) Tests with Milsana(R) and *Brevibacillus brevis* for side effects against *Typhlodromus pyri* (Acari, Phytoseiidae) and *Aphidius rhopalosiphi* (Hymenoptera, Braconidae). In 'Proceedings of the 10th International Conference on Cultivation Technique and Phytopathological Problems in Organic Fruit Growing and Viticulture. Weinsberg, Germany, 4-7 February 2002. p231-235.'.

Shaul O, Elad Y, Kirshner B, Volpin H, Zieslin N (1992). Control of *Botrytis cinerea* in cut rose flowers by gibberellic acid, ethylene inhibitors and calcium. In 'Recent Advances in *Botrytis* research. Proceedings of the 10th International *Botrytis* symposium, Heraklion, Crete, Greece. 5 - 10th April 1992.'. pp. 257-261. (Pudoc Scientific Publishers.: Wageningen, The Netherlands)

Shaul, O, Elad, Y, Zieslin, N (1995a). Suppression of *Botrytis* blight in cut rose flowers with gibberellic acid: effect of concentration and mode of application. *Postharvest Biology and Technology* **6(321-330)**.

Shaul, P, Elad, Y, Zieslin, N (1995b). Suppression of *Botrytis* blight in cut rose flowers with gibberellic acid: effects of postharvest timing of the gibberellin treatment, conidial inoculation and cold storage period. *Postharvest Biology and Technology* **6**, 331-339.

Shaw, KE, Davidson, G, Clark, SJ, Ball, BV, Pell, JK, Chandler, D, Sunderland, KD (2002). Laboratory bioassays to assess the pathogenicity of mitosporic fungi to Varroa destructor (Acari: Mesostigmata), an ectoparasitic mite of the honey bee, Apis mellifera. *Biological Control* **24(3)**, 266-276.

Shitole, DM, Patil, UR, Pawar, NB (2000). In vitro evaluation of chemicals and antibiotics against important fruit rotting fungi of strawberry. *Journal of Maharashtra Agricultural Universities* **25(2)**, 179-181.

Siddiqui, ZA, Mahmood, I (1996). Biological control of plant parasitic nematodes by fungi: a review. *Bioresource Technology* **58(3)**, 229-239.

Siggelkow, C, Jackel, B (1998). Side effects of plant tonics on predatory mites. *Nachrichtenblatt des Deutschen Pflanzenschutzdienstes* **50(11)**, 278-284.

Singh, RR, Narain, U, Singh, M (1997). Efficacy of different fungicides for control of early blight of potato caused by Alternaria solani. *Annals of Plant Protection Sciences* **5(1)**, 114-115.

Sirca, M (2001). AQ-10 - a unique biofungicide based on *Ampelomyces quisqualis* against various pathogens. *Proceedings of the 5th Slovenian Conference on Plant Protection, Catez ob Savi, Slovenia, 6 - 8 March 2001.* 174-179.

Smilanick JL, Margosan DA, Mlikota F, Usall J, Michael IF (1999). Control of citrus green mold by carbonate and bicarbonate salts and the influence of commercial postharvest practices on their efficacy. *Plant-Disease* **83(2)**, 139-145; 41 ref.

Stanghellini, M (1997). Inert components: are they really so? *Phytoparasitica* **25(Supplement)**, 81S-86S.

Stanghellini, ME, Kim, DH, Rasmussen, SL, Rorabaugh, PA (1996). Control of root rot of peppers caused by Phytophthora capsici with a nonionic surfactant. *Plant Disease* **80(10)**, 1113-1116.

Stanghellini, ME, Miller, RM (1997). Biosurfactants: their identity and potential efficacy in the biological control of zoosporic plant pathogens. *Plant Disease* **81(1)**, 4-12.

Stanghellini, ME, Nielsen, CJ, Kim, DH, Rasmussen, SL, Rorbaugh, PA (2000). Influence of sub- versus top-irrigation and surfactants in a recirculating system on disease incidence caused by Phytophthora spp. in potted pepper plants. *Plant Disease* **84(10)**, 1147-1150.

Stanghellini, ME, Rasmussen, SL, Kim, DH, Rorabaugh, PA (1996). Efficacy of nonionic surfactants in the control of zoospore spread of Pythium aphanidermatum in a recirculating hydroponic system. *Plant Disease* **80(4)**, 422-428.

Stanghellini, ME, Tomlinson, JA (1987). Inhibitory and lytic effects of a nonionic surfactant on various asexual stages in the life cycle of Pythium and Phytophthora species. *Phytopathology* **77(1)**, 112-114.

Stirling, AM, Pegg, KG, Hayward, AC, Stirling, GR (1999). Effect of copper fungicide on Colletotrichum gloeosporioides and other microorganisms on avocado leaves and fruit. *Australian-Journal-of-Agricultural-Research* **50(8)**, 1459-1468; 29 ref.

Stirling M, Stirling G (1997). Disease Management: Biological Control. In 'Plant Pathogens and Plant Diseases'. (Eds JF Brown and HJ Ogle) pp. 427-439. (Rockvale Publications: Armidale, NSW)

Stone, AG, Vallad, GE, Cooperband, LR, Rotenberg, D, Darby, HR, James, RV, Stevenson, W, Goodman, RM (2003). The effect of organic amendments on soil-borne and foliar diseases in field-grown snap bean and cucumber. *Plant Disease* **87**, 1037-1042.

Sturz, AV, Ryan, DAJ, Coffin, AD, Matheson, BG, Arsenault, WJ, Kimpinski, J, Christie, BR (2004). Stimulating disease suppression in soils: sulphate fertilizers can increase biodiversity and antibiosis ability of root zone bacteria against Streptomyces scabies. *Soil Biology and Biochemistry* **36(2)**, 343-352.

Tate, KG, Van der Mespel, GJ (1985). Control of peach leaf curl. *Orchardist of New Zealand* **58(2)**, 94-95.

Thakur, DP, Singh, JP (1983). Post harvest decay of ripe tomato fruits caused by Cladosporium oxysporum. *Indian Phytopathology* **recd. 1986, 36(4)**, 723-724.

Thangavelu, R, Palaniswami, A, Velazhahan, R Mass production of Trichoderma harzianum for managing fusarium wilt of banana. *Agriculture, Ecosystems & Environment* **In Press, Corrected Proof**.

Timm, L, Pearson, D, Jaffee, B (2001). Nematode-trapping fungi in conventionally and organically managed corn-tomato rotations. *Mycologia* **93(1)**, 25-29.

Timmer, LW (1988). Evaluation of bactericides for control of citrus canker in Argentina. *Proceedings of the Florida State Horticultural Society* **publ. 1989, 101**, 6-9.

Tirilly, Y (1991). The role of fosetyl-A1 in the potential integrated control of Fulvia fulva. *Canadian Journal of Botany* **69(2)**, 306-310.

Tjosvold SA, Koike ST, Zieslin N (ed.), Agbaria H (2001). Evaluation of reduced risk and other biorational fungicides on the control of powdery mildew on greenhouse roses. *Proceedings of the Third International Symposium on Rose Research and Cultivation, Herzliya, Israel, 21-26 May 2000. Acta-Horticulturae. 2001, No. 547, 59-67; 1 ref* .

Tomlinson, JA, Thomas, BJ (1986). Studies on melon necrotic spot virus disease of cucumber and on the control of the fungus vector (Olpidium radicale). *Annals of Applied Biology* **108(1)**, 71-80.

Topolovec-Pintaric, S, Cvjetkovic, B, Jurjevic, Z (1999). Experience in integrated chemical-biological control of grey mould (*Botrytis cinerea*) on grapevines in Croatia. *Journal of Wine Research* **10(1)**, 33-41.

Touart, AP (2000). Time for (compost) tea in the Northwest. *BioCycle* **41(10)**, 74-77.

Tsahouridou, PC, Thanassoulopoulos, CC (2002). Proliferation of Trichoderma koningii in the tomato rhizosphere and the suppression of damping-off by Sclerotium rolfsii. *Soil Biology and Biochemistry* **34(6)**, 767-776.

United States Environmental Protection Agency (2004). Integrated Pest Management (IPM) and Food Prodction. **http://www.epa.gov/pesticides/factsheets/ipm.htm**.

Utkhede, RS, Mathur, S (2002). Biological control of stem canker of greenhouse tomatoes caused by Botrytis cinerea. *Canadian Journal of Microbiology* **48(6)**, 550-554.

Vallad, GE, Cooperband, L, Goodman, RM (2003). Plant foliar disease suppression mediated by composted forms of paper mill residuals exhibits molecular features of induced resistance. *Physiological and Molecular Plant Pathology* **63(2)**, 65-77.

van Os, GJ, van Ginkel, JH (2001). Suppression of Pythium root rot in bulbous Iris in relation to biomass and activity of the soil microflora. *Soil Biology and Biochemistry* **33(11)**, 1447-1454.

Van Rhee JA (1967). Development of earthworm populations in orchard soils. In 'Progress in Soil Biology.'. (Eds O Graff and J Satchel) pp. 360-371. (North Holland Publishing Company: Amsterdam, Netherlands)

Van Zwieten, L, Kingston, T, Cox, J, Ayres, M, Walker, B, Hotson, I, Morris, S (2003). Healthy soils in Macadamia orchards. *Australian Nutgrower* **17(2)**, 18-24.

Van Zwieten, L, Rust, J, Kingston, T, Merrington, G, Morris, S Influence of copper fungicide residues on occurrence of earthworms in avocado orchard soils. *Science of The Total Environment* **In Press, Corrected Proof**.

Vanneste JL, Voyle MD, Zydenbos SM (2003). Genetic basis of copper resistance in New Zealand strains of Pseudomonas syringae. In 'New-Zealand-Plant-Protection.-Proceedings-of-a-conference,-Chateau-on-the-Park,-Christchurch,-New-Zealand,-12-14-August-2003.'. pp. 109-112.

Vecchione A, Luca F de, Sannicolo M, Pertot I, de Luca F, Brunelli A (ed.), Canova A (2002). Efficacy of some natural compounds against strawberry powdery mildew. *Atti,-Giornate-fitopatologiche,-Baselga-di-Pine,-Trento,-Italy,-7-11-aprile-2002,-Volume-2. 2002, 441-442; 3 ref* .

Viret, O, Ancay, A, Terrettaz, C (1998). Powdery mildew of strawberries (Sphaerotheca aphanis (Wallr.) U. Braun): effects of the fungicide applications in autumn on yield and fruit quality. *Revue Suisse de Viticulture, d'Arboriculture et d'Horticulture* **30(4)**, 265-269.

Volpin, H, Elad, Y (1991). Influence of calcium nutrition on susceptibility of rose flowers to *Botrytis* blight. *Phytopathology* **81**, 1390-1394.

Ware GW (1978) 'The Pesticide Book.' (W.H. Freeman and Company: San Francisco)

Warren R, Ryder M (2003) 'Soil biological constraints and benefits to quandong and other native food production.' (Rural Industries Research and Development Corporation, Kingston, ACT)

Washington, WS, Engleitner, S, Boontjes, G, Shanmuganathan, N (1999). Effect of fungicides, seaweed extracts, tea tree oil, and fungal agents on fruit rot and yield in strawberry. *Australian-Journal-of-Experimental-Agriculture* **39(4)**, 487-494; 33 ref.

Washington, WS, Shanmuganathan, N, Forbes, C (1992). Fungicide control of strawberry fruit rots and the field occurrence of resistance of Botrytis cinerea to iprodione, benomyl and dichlofluanid. *Crop Protection* **11(4)**, 355-360.

Westney, C (2002). Milk makes wine fine: Dairy sprays protect grapevines from powdery mildew. **www.nature.com/nsu/020916/020916-5.html**.

White, RF (1979). Acetylsalicyclic acid (aspirin) induces resistance to tobacco mosaic virus in tobacco. *Virology* **99**, 410-412.

Wickland, L, Murray, T, Jimerson, J (2001). Brewing up solutions to pest problems. *BioCycle* **42(3)** , 64-66.

Wilson, CL, El Ghaouth, A, Chalutz, E, Droby, S, Stevens, C, Lu, JY, Khan, V, Arul, J (1994). Potential of induced resistance to control postharvest diseases of fruits and vegetables. *Plant Disease* **78**, 837-844.

Wilson, M (1997). Biocontrol of aerial plant diseases in agriculture and horticulture: current approaches and future prospects. *Journal-of-Industrial-Microbiology-and-Biotechnology* **19(3)**, 188-191; 55 ref.

Wilson, M, Moss, WP, Ji, P, Wang, SY, Dianese, AC, Zhang, D, Campbell, HL, Duffy, B (ed.), Rosenberger, U (ed.), Defago, G (1998). Molecular approaches in the development of biocontrol agents of foliar and floral bacterial pathogens. *Molecular approaches in biological control.* **21(9)**, 247-255.

Winding, A, Binnerup, SJ, Pritchard, H (2004). Non-target effects of bacterial biological control agents suppressing root pathogenic fungi. *FEMS Microbiology Ecology* **47(2)**, 129-141.

Wu, WS (1998). The effects of bioagent-amended potting medium to control Rhizoctonia solani, Phytophthora capsici and Pythium aphanidermatum for cultivating healthy horticultural crops. *Plant Pathology Bulletin* **7(1)**, 54-65.

Yoder, OC, Whalen, ML (1975). Factors affecting posthavest infection of stored cabbage tissue by *Botrytis cinerea*. *Canadian Journal of Botany* **53**, 691-699.

Yu, H, Sutton, JC (1997). Effectiveness of bumblebees and honeybees for delivering inoculum of Gliocladium roseum to raspberry flowers to control Botrytis cinerea. *Biological Control* **10(2)**, 113-122.

Zhang, XJ, Wang, JS, Fang, ZD (1993). Control of potato soft rot (Erwinia carotovora subsp. carotovora (Jones) Dye) by copper sulphate and its effect on some enzymes in tubers. *Acta Phytopathologica Sinica* **23(1)**, 75-79.

Ziv, O, Hagiladi, A (1993). Controlling powdery mildew in Euonymus with polymer coatings and bicarbonate solutions. *HortScience* **28(2)**, 124-126; 13 ref.

Ziv, O, Shifris, C, Grinberg, S, Fallik, E, Sadeh, A (1994). Control of Leveillula taurica mildew (Oidiopsis taurica) on pepper plants. *Hassadeh* **74(5)**, 526-532; 13 ref.

Ziv, O, Zitter, TA (1992). Effects of bicarbonates and film-forming polymers on cucurbit foliar diseases. *Plant-Disease* **76(5)**, 513-517; 24 ref.

Appendix 1 Press release

Text Box 1: Media Release

NSW Agriculture

News Release

5.5.2003

NSW Agriculture seeks information on organic products

NSW Agriculture is investigating alternatives to copper-based fungicides for use in organic farming systems and is calling for companies and individuals to come forward with information on alternative products that can control plant diseases.

The project aims to conduct a thorough review of literature on existing technologies that may replace or complement copper for plant disease control.

Dr Lukas Van Zwieten, a research scientist based at Wollongbar Agricultural Institute who heads up the project, said the end product would include a list of products available to the Australian organics industry.

"Copper has been used for centuries around the world to reduce pests and diseases," said Lukas.

"Its use in both conventional and organic agriculture has lead to copper accumulation in the soil, which has a detrimental effect on soil fauna, including bacteria, fungi and earthworms," he said.

"A diverse, abundant soil fauna has been shown to outcompete and exclude pathogenic organisms in many trials around the world. Measures should be taken to protect organisms that compete with pathogens."

Both in Australia and internationally, the use of copper-based fungicides is subject to restrictions in organic agriculture.

“This limits organic farmers’ ability to deal with crop diseases, especially when disease pressure is high."

“Organic producers urgently require alternatives to be identified, and ultimately scientifically-evaluated.”

The project team is keen to investigate natural products, such as molasses, that “feed” the friendly micro-organisms and may control some fungal diseases.

Other strategies include the use of compost and compost teas, vermiculture products and microbial inoculants.

“These commercially-available products have been marketed to the organic industry as increasing soil organisms and protecting crops from pathogens,” Lukas said.

“They may or may not have undergone independent, rigorous scientific evaluation, making it difficult for farmers to judge their worth.

"The reason some products are successful has not been satisfactorily identified. Further research may provide improvements in their efficacy.”

The project is co-funded by the Rural Industries Research and Development Corporation (RIRDC). Plant pathologist Dr Melissa Van Zwieten is collecting the information regarding copper-alternative products.

Companies or individuals with information should contact Dr Melissa Van Zwieten (Phone: (02) 6626 1126; fax: 6628 3264; email: melissa.van.zwieten@agric.nsw.gov.au) so their copper alternative product can be included in the review.

Media contact: Dr Lukas Van Zweiten, NSW Agriculture, Wollongbar (02) 6626 1200.

www.agric.nsw.gov.au/news/releases/

Appendix 2 Fungicide classes

Table A2: Fungicide Activity Group List

GROUP	FUNGICIDE CLASS	ACTIVITY GROUP	CHEMICAL GROUPING	ACTIVE CONSTITUENT	TRADE NAME
A	Specific	*Benzimidazole*	*Benzimidazole*	benomyl	Benlate®
				carbendazim	*various* eg Bavistin®
				thiabendazole	Tecto®
				thiophanate-methyl	Topsin M®
B	Specific	*Dicarboximide*	*Dicarboximide*	iprodione	Rovral®
				procymidone	Sumisclex®, Fortress®
C	Specific	*DMI (or Ergosterol biosynthesis inhibitors)*	*Imidazole*	imazalil	*various* eg Fungaflor®, Magnate®
				prochloraz	*various* eg Octave®
			Piperazine	triforine	Saprol®
			Pyrimidine	fenarimol	Rubigan®
			Triazole	bitertanol	Baycor®
				cyproconazole	Alto®
				cyproconazole (+ chlorothalonil)	Bravo® Plus
				cyproconazole (+ iodocarb)	Garrison®
				diclobutrazole	Vigil®
				difenoconazole	Score®, Bogard®
				epoxiconazole	Opal®
				fluquinconazole	Jockey®
				flusilazole	Cane Strike®, Nustar®
				flutriafol	*various* eg Armour®
				hexaconazole	Anvil®
				myclobutanil	Systhane®, Mycloss®
				paclobutrazol	Cultar®
				penconazole	Topas®
				propiconazole	*various* eg Tilt®
				tebuconazole	Raxil®, Folicur®

GROUP	FUNGICIDE CLASS	ACTIVITY GROUP	CHEMICAL GROUPING	ACTIVE CONSTITUENT	TRADE NAME
				tetraconazole	Eminent®, Domark®
				triadimefon	*various* eg Bayleton®
				triadimenol	Bayfidan®, Shavit®
				triticonazole	Premis®, Real®
D	Specific	*Phenylamide*	*Acylamine*	benalaxyl (+ mancozeb)	Galben®M
				furalaxyl	Fongarid®
				metalaxyl	Ridomil®
				metalaxyl (+ copper oxychloride)	Ridomil® Plus
				metalaxyl (+ mancozeb)	Ridomil® MZ
				metalaxyl-m	Ridomil® Gold
				metalaxyl-m (+ mancozeb)	Ridomil® Gold MZ
			Oxazolidinone	oxadixyl (+ mancozeb)	Recoil®
				oxadixyl (+ propineb)	Fruvit®
E		*Morpholine*	*Morpholine*	tridemorph	Calixin®
			Spiroketalamine	spiroxamine	Prosper®
F	Specific	*Phosphorothiolate*	*Organophosphorous*	pyrazophos	Afugan®
G	Specific	*Oxathiin*	*Anilide*	carboxin	Vitavax®, Regatta®
				flutolanil	Moncut®
				oxycarboxin	Plantvax®
				boscalid	Filan®
H	Specific	*Hydroxy-pyrimidine*	*Pyrimidinol*	bupirimate	Nimrod®
I		*Anilino-pyrimidine*	*Anilinopyrimidine*	cyprodinil	Chorus®
				cyprodinil (+ fludioxinil)	Switch®
				pyrimethanil	Scala®
				pyrimethanil (+ chlorothalonil)	Walabi®
J		*Hydroxyanilide*	*Hydroxyanilide*	fenhexamid	Teldor®
K		*Strobilurin*	*Strobilurin*	azoxystrobin	Amistar®
				kresoxim-methyl	Stroby®
				pyraclostrobin	Cabrio®

GROUP	FUNGICIDE CLASS	ACTIVITY GROUP	CHEMICAL GROUPING	ACTIVE CONSTITUENT	TRADE NAME
				trifloxystrobin	Flint®
L		*Phenylpyrroles*	*Phenylpyrroles*	fludioxonil	Maxim®
M		*Phenoxy quinoline*	*Phenoxy quinoline*	quinoxyfen	Legend®
Y	Protectant	*Multi-site activity*	*Carbamate*	iodocarb	
				propamocarb	Previcur®
			Phosphonate	fosetyl-al	Aliette®
				phosphorous acid	*Various*
			Inorganic	chlorine dioxide	Vibrex Flora®
				copper cuprous oxide	*Various*
				copper hydroxide	*Various*
				copper oxychloride	*Various*
				copper octanoate	Tricop®
				hydrogen peroxide + peroxyacetic acid	Peratec®
				iodine	Ultra Dyne C®
				mercury	Shirtan®
				sodium metabisulphite	Uvas Quality Grapeguard®
				sulphur	*various* eg Thiovit®, Kumulus®
			Dithiocarbamate	mancozeb	*various* eg Dithane®
				metiram	Polyram®
				thiram	*various* eg Thiram®
				propineb	Antracol®
				zineb	*various* eg Zineb®
				zineb (+ copper oxychloride)	Copper Curit®
				ziram	*various* eg Ziram®
			Phthalimide	chlorothalonil	*various* eg Bravo®
			Chlorophenyl	quintozene	Terrachlor®
			Quinone	dithianon	Delan®
			Hydroxyquinoline	8-hydroxy quinoline sulphate	Chinosol®
			Pyradinamine	fluazinam	Shirlan®
			Cyclic imide	captan	Captan®, Merpan®
X	Specific	*(Unspecified)*	*Cinnamic acid derivative*	dimethomorph	Acrobat®
			Sulfamide	dichlofluanid	Euparen®

GROUP	FUNGICIDE CLASS	ACTIVITY GROUP	CHEMICAL GROUPING	ACTIVE CONSTITUENT	TRADE NAME
				tolyfluanid	Euparen Multi®
			Dinitrophenyl	dinocap	Karathane®
			Organophosphate	tolclofos-methyl	Rizolex®
			Guanidine	dodine	*various* eg Dodine®
				guazatine	Panoctine®
			Thiadiazole	etridiazole	Terrazole®
			Quinoxaline	oxythioquinox	Morestan®
				pencycuron	Monceren®

Source: (Avcare 2003; Letham and Stovold 1995)

Note: -Some products are mixtures of fungicides from different activity groups. These appear only once in the chart. If multiple trade names exist, the trade name entry is listed as various and a common tradename included.

Appendix 3 Product descriptions

(Note: Please refer to disclaimer in relation to this appendix)

Vigor-Cal^{TM} (description derived from company brochure)	
DISTRIBUTER	Agro-K Corporation
PRODUCT DESCRIPTION	Bio-available calcium
PRODUCT DETAILS	Vigor-Cal^{TM} is a unique foliar product that contains a highly bio-available form of calcium design to improve a plant's systemic vigor and increase its natural resistance to fungal infections. It is compatible with liquid fertilizers and fungicides. It is the conventional and IPM answer to healthier plants. Vigor-Cal^{TM} provides a readily available and easily absorbable form of calcium (5%) to help prevent calcium deficiencies and balance the calcium/nitrogen ratio in plants. This ratio has been shown as an important factor in the predisposition of a plant to fungal infection.
USES	Vigor-Cal^{TM} will increase: • Plant cell wall thickness; • Internal resistance to fungal infection; • Overall plant health; • Quality of produce (fruits and vegetables); and, • Storage life of produce.
METHODS OF APPLICATION	Vigor-Cal^{TM} can be applied with conventional foliar spray equipment, ground sprayers, aerial applicators and overhead irrigation systems. Vigor-Cal^{TM} can be tank mixed with most foliar liquid fertilizers and fungicides. Application rate: 5 to 20 L/ha with sufficient water for thorough coverage.

Biomex Plus® with Trichoderma (description derived from company contact)	
DISTRIBUTER	Bio-energy Solutions
PRODUCT DESCRIPTION	Soil bacteria and fungi
PRODUCT DETAILS	Biomex Plus® with Trichoderma is a probiotis coil restorer. It is a microbial soil inoculum cultured with specially selected soil microbes (bacteria and fungi) plus Humic Acid. Biomex Plus® is non-toxic, environmentally and ecologically safe.
USES	Biomex Plus® works in the following ways: • Assists plant growth and development; • Helps the plant to develop and improve its natural resistance to diseases; • Reduces transplant losses and planting shock • Assists the plant to increase it's tolerance to drought, soil salinity and polluted soil conditions; • Helps reduce the plants need for inputs (e.g. fertilisers, fungicides and pesticides); and, • Assists the soil by increasing nutrient availability and water retention.
METHODS OF APPLICATION	Biomex Plus® is applied to the soil

Vam-OZ® (description derived from company contact)	
DISTRIBUTER	Bio-energy Solutions
PRODUCT DESCRIPTION	Endo mycorrhizial fungi inoculant
PRODUCT DETAILS	Vam-OZ® contains the species *Glomus intaradices*, a water-holding polymer, nutrients and bio-stimulants.
USES	
METHODS OF APPLICATION	Vam-OZ® is applied to the soil

Effective Microorganisms (EM) (information derived from company information and publications).	
DISTRIBUTER	Eco Organics/EM Research Australia Pty Ltd
PRODUCT DESCRIPTION	microbial inoculant
PRODUCT DETAILS	**EM -** effective microorganisms, group of beneficial, naturally occurring, nonpathogenic, and food-grade microorganisms. Comprised mainly of lactic acid bacteria, yeast and photosynthetic bacteria, including aerobic and anaerobic microorganisms. **EM-5 -** composed of water, molasses, vinegar, alcohol, red chili pepper and other organic materials and fermented with EM. Also known as Stochu. **EM Bokashi -** organic fertilizer, composed of rice bran, oil cake, fish meal, and other organic materials and fermented with EM solution (EM-1, molasses, and water).
USES	EM is a combination of various beneficial, naturally-occurring microorganisms mostly used for or found in foods. It contains beneficial organisms from three main genera: phototrophic bacteria, lactic acid bacteria and yeast. These effective microorganisms secrete beneficial substances such as vitamins, organic acids, chelated minerals and antioxidants when in contact with organic matter. They change soil microflora and fauna so that disease-inducing soil becomes disease-suppressing soil which in turn has the capability to develop into azymogene soil. The antioxidation effects of these microorganisms pass directly to the soil or indirectly to plants maintaining their NPK and CN ratio. This process increases the humus content of the soil and is capable of sustaining high-quality food production. Effective microorganisms were developed over many years in liquid form by Prof. Dr. Teruo Higa of the University of the Ryukyus, and finished in 1982. At first, EM was considered an alternative for agricultural chemicals. But its use has now spread to applications in environmental, industrial and health fields. Literature surveys have identified EM products as anti-fungal agents, however, these claims are not made by the Australian distributor.
METHODS OF APPLICATION	**Tropical and sub-tropical land:** Such lands have higher amounts of moisture, organic matter and soil organisms. One dose of 20 L of EM and 2 – 4 tonnes of EM Compost per acre per crop is recommended. 1 litre bottles (makes 100 litres when activated).

Citrofresh® (description derived from company brochure)	
DISTRIBUTER	GDM Technologies Pty Ltd
PRODUCT DESCRIPTION	A phyto-pharmaceutical of citrus fruit and vegetation origin.
PRODUCT DETAILS	Citrofresh® has anti-pathogenic power due to a synergistic activity which is created between citrus fruit bioflavonoid complex and certain other naturally occurring organic acids. The products are carried in a food sage solvent (glycerine), which makes the product infinitely soluble in water.
USES	Fresh produce decontamination, plant growth promotors, livestock and fish decontamination, animal feed supplements. Citrofresh® benefits: • Is a new and unique phyto-pharmaceutical; • Is a wholly natural organic compound • Has a broad-spectrum anti-microbial activity, which works against bacteria (gram positive and negative), viruses, moulds, yeast and fungi. • In non-mutagenic, non-carcinogenic, non-toxic, non-corrosive, non-tainting and non-volatile; • Has extended action (residual effect), but does not possess a knock down (shock action); • Has the ability to break down biofilm; • Is effective even in the presence of organic matter; • Its mechanism of action in by the destruction of the cell wall.
METHODS OF APPLICATION	**Preharvest and Postharvest:** up to 5% in solution

Croplife® (description derived from company brochure)	
DISTRIBUTER	GDM Technologies Pty Ltd
PRODUCT DESCRIPTION	A nutrient synergist.
PRODUCT DETAILS	Croplife® is designed to improve plant vigour and reduce stress by providing supplemental vitamins and nutrients to the plant. The key component also provides the means for the calcium, an inert and not normally readily absorbed mineral, to be absorbed through the leaves.
USES	Horticultural Crops: apples, pears, strawberries, grapes, potatoes, flowers. Croplife®: • Improves the intake of foliar applied nutrients; • Assists transport of all minerals through the plant leaves; • Enables plants to withstand higher pest and disease thresholds; and, • Environmentally responsible and 100 % biodegradable.
METHODS OF APPLICATION	**Horticultural crops:** Strawberries: up to 300 mL/ha (applied with sufficient water to ensure coverage) Vegetables: up to 270 mL/ha Fruit: up to 270 mL/ha Vines: up to 270 mL/ha Higher rates should be applied if risk of damage from pest or disease pressure is high.

Liquicop® Copper Fungicide (description derived from company brochure)	
DISTRIBUTER	Lefroy Valley/Hygrotech Oceania
PRODUCT DESCRIPTION	Low copper-based fungicide
PRODUCT DETAILS	Liquicop® Copper Fungicide is designed as a low copper based product. The active constituent is 80 g/L copper present as copper ammonium acetate. To improve plant vigour and reduce stress by providing supplemental vitamins and nutrients to the plant. The key component also provides the means for the calcium, an inert and not normally readily absorbed mineral, to be absorbed through the leaves.
USES	A copper fungicide solution for the control of various diseases of fruit and vegetables. Examples of diseases: Bean: common blight, bacterial brown spot and rust; Carrot: leaf spot; Celery: bacterial soft rot; Onion: downy mildew; Potato: late blight; Banana: cercospora leaf spot Apple: black spot Avocado: anthracnose, phytophthora stem canker; Mango: bacterial spot; Vines: downy mildew; and Macadamia: phytophthora stem canker.
METHODS OF APPLICATION	Fill the spray tank to three quarters of the required colume of water, then slowly pour Liquicop® into the spray tanks, with the agitation system actively moving. Add any tank-mix products to the spray tank after Liquicop® if thoroughly mixed. Top-up to the required volume with water. **Non tree, non vine and fruit crops:** Beans, capsicum, carrot, celery, cucurbits, onions, potatoes, tomatoes, brassicas, silverbeet, banana, strawberry and ornamentals: *High volume sprayer*: 500 mL/100 L water; *Air or ultra low volume sprayer*: 2.5 L/ha. Apply every 7 – 14 days depending on disease pressure. **Tree and vine crops:** Apple, apricot, avocado, citrus, mango, vines (wine and table grapes) and macadamias: Generally: 500 mL/100 L water (range 250 – 625 mL/100L) Apply at either predetermined growth stage (e.g. in Apricot at bud swell) or at first sign of disease.

Citrox® 14W (derived from Company web information http://www.citrox.com/ and company brochure)	
DISTRIBUTER	Natural Agricultural Products Pty Ltd
PRODUCT DESCRIPTION	Phyto- pharmaceutical
PRODUCT DETAILS	Citrox® 14W is a bioflavanoid complex which is extracted from the pith and pulp of bitter oranges, it is not an oil. The bioflavanoid extract when combined with other natural organic acids such as citric acid produces an extremely powerful anti-bacterial, anti-viral, anti-mould and anti-fungal agent. This powerful agent destroys any bacteria, virus, mould or fungus that is present while leaving a food sage, non toxic film that keeps bacteria from multiplying.
USES	Used for sanitising benches and equipment. It is also used as a fruit wash (e.g. apples and pears) prior to packing. Kills bacteria, virus's, mould and fungi in processed foods, water. No claims made for fungicidal uses in agricultural crops. Features include: • Is a wholly natural organic product; • Has a broad-spectrum anti-microbial activity (bacteria, viruses, moulds, yeast and fungi); • Is non-mutagenic, non-carcinogenic, non-toxic, non-corrosive, non-tainting and non-volatile; • Has extended action (residual effect) but does not possess a knock down (shock action); • Has the ability to break down biofilm; • Is effective in the presence of organic matter; • Its mechanism of action is by the destruction of the cell wall; • Stable at pH levels from 2 to 12 and temperatures up to 130 °C; and • Retains it's stability when exposed to light.
METHODS OF APPLICATION	Mix at rate: 1 ml Citrox® 14W to 1 L water. This mixture is used as a spray to sanitise anything that may contain or harbour bacteria in a food preparation area.

NUTRI-LIFE TRICHOSHIELD™ (description derived from company brochure)	
DISTRIBUTER	Nutri-Tech Solutions
PRODUCT DESCRIPTION	*Trichoderma* spp inoculant
PRODUCT DETAILS	A lignite-based formulation, containing 100 million spores per gram of *trichoderma harzianum* and *trichoderma lignorum.* Trichoderma is a predatory fungus that devours a wide range of pathogenic fungi. TrichoShield™ is just 30% of the cost of equivalent formulations.
USES	Seed treatment creates a protected environment with a variety of plant health benefits. Trichoderma is an internationally recognised Mycofungicide. The product is not legally permitted to make any fungicidal claims ie the product is not yet registered in Australia, where natural bio-protectors still require the same registration as chemical fungicides.
METHODS OF APPLICATION	**Dry Seed Treatment:** Mix in 5 g of Nutri-Life Trichoshield™ per kg of seed. **Slurry Seed Treatment:** Add 5 g of Nutri-Life Trichoshield™ to 100 ml of water per kg of seed. Air-dry seed before sowing. **Broadcast:** Mix 1 kg of Nutri-Life Trichoshield™ with 100 to 500 kg of Nutri-Store 180 (or similar) per hectare. **Fertigation or Boom-spray:** Mix 1 kg of Nutri-Life Trichoshield™ with 200 litres of water. Screen before use. Dilute 1 kg of Nutri-Life Trichoshield™ in 2 litres of water. Stand for one hour, screen, then add to 100 to 200 litres of water per hectare. **Foliar Spray:** Dilute 1 kg of Nutri-Life Trichoshield™ in 2 litres of water. Stand for one hour, screen, then add to 300 to 400 litres of water per hectare.

NUTRI-LIFE B.*sub*™ (description derived from company brochure)	
DISTRIBUTER	Nutri-Tech Solutions
PRODUCT DESCRIPTION	*Bacilus subtilis* inoculant
PRODUCT DETAILS	A beneficial fungal strain Bacilus *subtilis* that is antagonistic to powdery and downy mildews. Powdery mildew and Downey mildew are important diseases of crops worldwide. If uncontrolled, the diseases can be devastating. Powdery mildew [PM] can be caused by many fungi. PM can result in reduced plant growth, yield, and fruit quality. A white powdery growth develops on leaves, buds and twigs causing them to be distorted and dwarfed. Young, tender growth is most susceptible. The disease is more likely to occur during cool, dry conditions and can spread rapidly since a complete life cycle can occur in 72 hours. Thousands of spores are produced on a single plant with each having the ability to cause disease. Downey mildew [DM] is a fungal disease and is common in grape growing areas of the world with high humidity during the growing season. DM is first observed as small, pale yellow to reddish spots on the upper leaf surface with white downy growth on the lower surface. Infected leaves are killed and turn brown and may fall off. Young infected shoots and cluster stems may curl, distort, show thickening of the infected tissue and may be covered with a whitish fungal mass. Infected berries turn brown and eventually shrivel. Infections are triggered by warm, humid nights followed by rain.
USES	Can be used at all stages of crop growth No toxic residues Environmentally friendly, does not disturb ecological balance Non-toxic to animals, plants and humans Can be used for organic farming
METHODS OF APPLICATION	**Foliar:** Dilute at 1 : 1000 with water every 15 days. Can be applied at any stage. Thorough coverage is essential for optimum results. Spraying should be carried out in the evening to create favourable conditions for germination of *Bacillus subtilis* spores.

NUTRI-LIFE 4/20 (description derived from company brochure)	
DISTRIBUTER	Nutri-Tech Solutions
PRODUCT DESCRIPTION	*Trichoderma spp* / and mixed microbial inoculant
PRODUCT DETAILS	Nutri-Life 4/20 is a potent blend of 20 species of soil-friendly bacteria and 4 predatory fungi which devour and out-compete many pathogens. One of these species *Trichoderma* is renowned for its capacity to control several soil diseases including *Fusarium, Pythium, Rhizoctonia, Armillaria* and *Phytophthora*. Available as dry granules that must be activated with water and a food source and brewed in drums or tanks for 24 hours. Freshly brewed microbes are far less expensive and far more effective than the pre-bottled, liquid products.
USES	• Better nutrient uptake • Nitrogen fixation • Improved soil structure • Faster decomposition • Soil detoxifying • Higher organic carbon conversion • Increased availability of phosphorus • The release of locked up trace elements **Nutri-Life 4/20** is now widely used in hydroponics to improve nutrient uptake **Nutri-Life 4/20** can also be used to clean up waterways, dams and all irrigation sources. It can also be used to improve septic tank performance.
METHODS OF APPLICATION	**Seed Treatment:** 12 litres of microbe concentrate per tonne of seeds. **Soil:** 20 - 100 litres of microbe concentrate per hectare. **Foliar:** 100 litres of microbe concentrate per hectare, diluted with 200 litres of water. Using **Nutri-Life 4/20** involves 800 to 900 billion microbes per litre. At the recommended rate of 40 litres per acre, the actual microbe injection involves 36 trillion per acre! This can be an exceptionally cost-effective and productive addition at just $4 per acre.

Trich-A-Soil® (description derived from company brochure)	
DISTRIBUTER	Organic Crop Protectants
PRODUCT DESCRIPTION	*Trichoderma spp* inoculant
PRODUCT DETAILS	A mix of *Trichoderma viride* and *Trichoderma harzianum*, at 1x 10^9 spores/g. Trich-A-Soil® has a very high count of *Trichoderma viride* and *T. harzianum*. Manufacturer's claim is over 16x the spore count of other similar products based on colony forming units / gram and application rates. Trich-A-Soil® is fully researched, developed and manufactured in Australia, making it suited to Australian conditions, and "fresher" than any other product on the market. Trich-A-Soil® contains selected Trichoderma spp. including one selected by Dr Percy Wong of the NSW Department of Agriculture.
USES	Used in turf, hydroponics, viticulture, nurseries and vegetable crops. When applied to turf or incorporated into other growing media Trich-A-Soil® will colonise at the root zone to provide a much healthier growing environment for plant roots.
METHODS OF APPLICATION	Make sure all measuring equipment, containers, and tanks are free of chemicals and chlorine. Weigh out required amount of Trich-A-Soil® and use a general household strainer or spray tank strainer to wash the product through into the spray tank or container. Add the required amount of Acadian SSE, Aminogro, molasses and Hydretain, agitate and apply soon after (filters less than 100 microns should be removed from nozzles or pump equipment to prevent blockages). ***Wettable Powder*** 1.25kg/ha. At planting. Apply to in-furrow or through Trickle tape at planting, and two follow-up applications 14 days apart if disease pressure is high. ***Granular*** 10kg/ha. At planting. Apply to in-furrow with seed or seedling or placement just below seed.

EcoCarb® (description derived from company brochure)	
DISTRIBUTER	Organic Crop Protectants
PRODUCT DESCRIPTION	Plant bio-stimulant containing potassium bicarbonate
PRODUCT DETAILS	EcoCarb® is a soluble powder which contains 856 g Activated Potassium Bicarbonate. EcoCarb® changes the pH on leaf surfaces making it more alkaline. This produces an unfavourable environment for the germination of fungal spores and damages the cell walls of fungal 'structures'. EcoCarb® has no residues.
USES	Used on roses, strawberries, tomatoes, grapes and cucumbers. Used on a regular basis has demonstrated suppression of a variety of diseases in agricultural/horticultural crops.
METHODS OF APPLICATION	EcoCarb® is a soluble powder requiring dilution with water before use. Half fill spray tank with water and add the required amount of EcoCarb® slowly to the tank. Maintain constant agitation of the spray tank while adding EcoCarb®. Continue to fill tank with water and add Synertrol Horti Oil® or Eco-Oil® when the tank is full. ***Grapes*****:** 4-5 kg/ha; apply on regular basis every 14 days and every 7 days when disease pressure is high. Apply with Eco-Oil® or Synertrol Horti Oil® at 250 mL/100L. Thorough coverage is essential so a minimum of 1000L/ha is recommended. Do not apply at less than 7 day intervals. ***Roses and Strawberries*****:** 4g/L; apply at first sign of disease. For best protection, apply every 7 – 10 days until conditions are no longer favourable for disease. Apply to run-off with Eco-Oil® at 500 mL/200L every second spray. ***Polyhouses, glasshouse crops, floraculture and gardens*****:** 4g/L or 4 kg/ha; apply at first sign of disease. For best protection, apply every 7 – 10 days until conditions are no longer favourable for disease. Apply to run-off with Eco-Oil® at 500 mL/200L every second spray.

Synertrol® Horti Oil (description derived from company brochure)	
DISTRIBUTER	Organic Crop Protectants
PRODUCT DESCRIPTION	Botanical Oil Concentrate
PRODUCT DETAILS	Synertrol® Horti Oil is a botanical oil concentrate for the addition to most horticultural pesticides, herbicides and foliar nutrients.
USES	When used as directed Synertrol® Horti Oil: Increases the wetting and penetration of foliar applied pesticides and fertilisers; Makes sprays more rainfast and reduces leaching of soil applied chemicals; Reduces spray drift by minimising the mist caused by shattering of spray droplets; Allows chemical application when plants are wet with dew if used with ULV applications; Helps protect unstable or volatile products from sunlight breakdown and slows spray evaporation; Reduces spray water volumes by increasing chemical spreading on the spray target surfaces; Acts as a spray deodouriser, reducing chemical odours; and No additional wetting agents or surfactants required when using Synertrol® Horti Oil.
METHODS OF APPLICATION	***Boom sprayer*: ** 250-500mL/100L; use lower dose rate when using low dose rate chemicals ***Orchard, Plantation, Vineyard, Treecrop*:** 250 mL/100L; maintain agitation during application. ***CDA Aerial, ULV or Misting Machine*:** 1-2L/ha; Maintain agitation during application ***Knapsack*:** 30-50 mL/10L; shake knapsack if left standing.

Acadian™ (description derived from company brochure)	
DISTRIBUTER	Organic Crop Protectants
PRODUCT DESCRIPTION	Bio-stimulant derived from marine algae
PRODUCT DETAILS	Acadian™ contains a multitude of naturally occurring plant growth hormones such as cytokinins (primary active ingredient), betaines, auxins and gibberellins as well as a matrix of plant nutrients, amino acids, carbohydrates and vitamins. Acadian™ is extracted from fresh *Ascophyllum nodosum*.
USES	Acadian™ enhances: • Marketable yields and quality; • Crop sizing, firmness, shape and colour; • Shelf life; • Resistance to environmental stress (antiocidant activity); • Insect and disease management (Systemic Acquired Resistance); • Nutrient Bioavailability (organic complexing); and Enzyme and protein synthesis.
METHODS OF APPLICATION	***Turf*:** 750 – 1000g/ha Acadian™ should be applied every 2 -4 weeks or immediately after any stress event. After use keep plastic bag sealed to maintain freshness.

Aminogro® (description derived from company brochure)	
DISTRIBUTER	Organic Crop Protectants
PRODUCT DESCRIPTION	An organic biostimulant
PRODUCT DETAILS	Aminogro® is derived from a unique microbial digestion process designed to maximise L-form free amino acid production. It is manufactured using a process called enzymatic hydrolysis. This process extracts amino acids from carefully selected marine waste material, utilising specific enzymes to break the peptide bond of protein. Unlike other types of hydrolysis (acid and alkaline) enzymatic hydrolysis extracts free L form amino acids which are biologically active (100% plant available).
USES	Aminogro®: • Improves Brix, Specific Gravity and Baumé levels in plants and fruit; • Improves fruit and flower colour, uniformity and size; • Improves post harvest storage life of vegetables and fruit; • Improves the stress tolerance levels of plants; • Enhances the natural pest and diseases resistance in plants; • Enhances the uptake and assimilation of trace mineral to rapidly correct minor micronutrient deficiencies; • Improves soil structure, water holding capacity and CEC levels; and, • Supplies organic nitrogen (glutamic acid) to the plant and soil.
METHODS OF APPLICATION	**Foliar applications:** To achieve best results with Aminogro® always apply with Synertrol® Horti Oil and spray top and underside of foliage. Vegetable crops and tomatoes: 10mL/L every 10-14 days Tree crops (nuts, stone fruit, mango): 10 mL/L every 20-30 days. **Soil Applications:** Application of Aminogro® should be applied or injected into the irrigation system towards the end of watering. Perennial crops: 40L/ha just prior to budswell, fruit set and vegetative flushing.

Cornell Fungicide Formula (derived from web information http://216.122.176.138/garden/wildlife/00july2.htm and literature)	
DISTRIBUTER	none available
PRODUCT DESCRIPTION	baking soda plus oil
PRODUCT DETAILS	In 4L of water add 3 to 4 teaspoons baking soda, 3 to 4 teaspoons vegetable oil, and one-half to one teaspoon dish detergent or insecticidal soap. Spray until it drips off the foliage, every 3 to 4 days.) Source (New York State Integrated Pest Management Program)
USES	A number of uses described by Kuepper *et al.* (2001) including control of blackspot, powdery mildew, anthracnose, blight.
METHODS OF APPLICATION	For a plant that is already showing signs of disease, first remove all of the diseased parts that you can reach. Then remove all of the mulch underneath the plant, spray The Formula liberally on the cleaned-up plant (and apply fresh mulch). Be sure your spray gets to the underside of any leaves. To protect a disease-prone plant remove all old mulch as above and then spray the plant well---again, paying particular attention to the undersides of the leaves, Don't spray in direct sun in the heat of the day. Early morning is good; late evening is fine too.

Milsana® (derived from web information http://www.epa.gov/pesticides/biopesticides/ingredients/tech_docs/brad_055809.htm and literature)	
DISTRIBUTER	KHH BioSci, Inc. (not available in Australia)
PRODUCT DESCRIPTION	*Reynoutria sachalinensis* plant extract
PRODUCT DETAILS	The technical grade active ingredient consists entirely of the dried and ground plant material from harvested *Reynoutria sachalinensis* (giant knotweed) plants grown for this purpose. The end-use product Milsana® Bioprotectant contains 5% of the ethanolic extract of *Reynoutria sachalinensis,* and is not manufactured by an integrated process. *Reynoutria sachalinensis* extract, which is used as a preventive treatment, is believed to induce a non-specific resistance against certain fungal diseases. The active ingredient appears to be a natural elicitor of phytoalexins, which induce the plant's natural "immune system", providing resistance in the host plant.
USES	For the control of various diseases such as powdery mildew and grey mould on ornamentals.
METHODS OF APPLICATION	Applications should be done using conventional ground or foliar application equipment. Mix Milsana® with water at a rate of 2 quarts (0.1 quart of the active ingredient) per 100 gallons of water. For use only on ornamental non-food greenhouse crops. Make no more than 6 applications per year. Application should start at the 4-6 leaf stage. Repeat at 7 to 10 day intervals.

Myco-Sin® (derived from web information http://home.clear.net.nz/pages/awelte/myco-sin.htm and literature)	
DISTRIBUTER	Sustain-Ability (not available in Australia)
PRODUCT DESCRIPTION	Clay preparation
PRODUCT DETAILS	Myco-Sin® comprises sulphuric acidic clay minerals (bentonite), deactivated yeast cell membranes, specially processed equisetum extracts, highly disperse silicic acid. The sulphuric acidic clay minerals release Aluminium ions which are the actual carriers of the prophylactic effect, and make up the foundation of the plans intrinsic immunity on the basis of an 'induced resistance'.
USES	Myco-Sin® is a restorative and a biological composite of plant health enhancing agents who help to promote diseae resistance on crops, such as pipfruit, grape, berryfruit, vegetable and flower. The interaction between plant nutrition, stress and disease pressure is influenced in favour of plant tissue, the nutrient uptake is increased and the biological soil activity improved through an induced resistance by applying Myco-Sin® as directed.
METHODS OF APPLICATION	Myco-Sin® has to be applied in a preventative way at a high water rate and has to be absorbed into the plant tissue before rain. The hardeningof the cuticula, epidermis and stomata, together with the acidic pH of 3.5 to 3.8 of the spray solution create an environment adverse to spore germination. The additional yeast cell and equisetum extracts further enhance this process, act as sticking and spreading agents, and support antagonists. Myco-Sin® is best used from greentip to 3rd post bloom at 10 – 14 day intervals and at a rate of 0.8 – 1.2 % of spray volume of 600-1200 L/ha.

Tri-D25® (description derived from company brochure)	
DISTRIBUTER	Zadco for Quality Gro Pty. Ltd.
PRODUCT DESCRIPTION	*Trichoderma spp* inoculant *note. Currently not available
PRODUCT DETAILS	A mix of *Trichodema koningii* and *Trichodema hazianum*.at 5 x 10^7 spores/g.
USES	These are beneficial soil fungi that antagonise fungi such as *Phythophthora spp, Rhizoctonia spp*,and *Botrytis spp.* TRI-D25 contains naturally occurring saprophytic soil fungus, which can be applied to cuttings, seeds, transplants, bulbs, grafts, compost, pots, and established crops. It can also be sprayed onto crops, and is beneficial to increase callusing of wounds.
METHODS OF APPLICATION	**Orchards** : Apply 1 kg of TRI-D25 per ha in early spring. TROPICAL FRUITS : Apply 1-2 kg of TRI-D25 per ha or drench trees with 5-10gr of TRI- D25 per Tree. Repeat if necessary 2-3 months later. TABLE & WINE GRAPE VINEYARDS : Apply 1 kg of TRI-D25 per ha . NEWLY PLANTED VINEYARDS : (Drench all rooted vines while planting them using 1 kg of TRI-D25 in enough water to drench 1000-1200 vines. **Foliar Applications** VINEYARDS & ORCHARDS : Spray 1 kg of TRI-D25 in enough water (TRI-D25 cannot be diluted) to cover 1 ha (preferably late afternoon). Repeat application 3-4 weeks later or when needed. **Green-House & Nurseries** **:** Spray 150gr of TRI-D25 per 100L of water per 400sqm every 2-3 weeks (preferably late afternoon).

Carbo-Max® (description derived from company brochure)	
DISTRIBUTER	Southern Minerals
PRODUCT DESCRIPTION	Oxidising carbon
PRODUCT DETAILS	Carbo-Max® contains Leonardite (a geological term for young brown coal. This product is unique. It has been formed, under low pressure and without a full metamorphosis taking place.
USES	Maddingley Brown Coal has unique qualities as a soil conditioner and carrier of nutrients. Leonardite is a great source of organic carbon and humic acid. Carbo-Max® stimulates: • Phosphorus release; • Increases micro-activity; and, • Balances soil nutrients.
METHODS OF APPLICATION	None available

Silica-K® (description derived from company brochure)	
DISTRIBUTER	Southern Minerals
PRODUCT DESCRIPTION	Mineral supplement
PRODUCT DETAILS	Silicon is the second most abundant element on the earth of which the earth's crust is formed. Most agronomists and soil nutritionists disregard silicon as an essential element in plant health mainly because the research knowledge of nutrition has centred on the traditional macro-element fertication. Evidence also exists that silicon stimulates the production of anti-fungal compounds called phenolics in infected leaf cells.
USES	Silica-K®: • Improves health and vigour; • Source of soluble silicon; • Contains natural macro and trace elements; and, • Prevents fungal and root disease.
METHODS OF APPLICATION	None available