VG99076

Identification of techniques to produce poultry manure and compost-tea and their benefits in vegetable production

Steven David
Organic Farming Systems

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VG99076

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Level 1
50 Carrington Street
Sydney NSW 2000

Telephone:	(02) 8295 2300
Fax:	(02) 8295 2399
E-Mail:	horticulture@horticulture.com.au

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Identification of Techniques to Produce Poultry Manure and Compost-tea and Their Benefits in Vegetable Production.

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Written by:

Steven David

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1. Media Summary

The demand for "clean" food, internationally, is reportedly growing faster than any other segment in the food industry. Environmentally sensitive forms of agriculture are being restricted in Australia by, amongst other factors, the availability of cost-effective inputs for growers and understanding of alternative vegetable production techniques.

Australian vegetable growers have been very slow to experiment with biological (organic) farming systems when compared to the proportion of land converted to organic growing methods in some European countries and the USA. Farmers in these countries are responding to the consumer demand for "clean" food and/or encouragement from governments to convert land to certified organic farming methods. This is important for Australian vegetable growers, as we need to be aware of trends in our major export markets and how to produce vegetables to new standards.

Compost-tea (compost water extracts) is one exciting natural development that has been used in Europe and the USA for many years as foliar and soil sprays to effectively prevent or reduce the incidence of fungal disease in horticultural crops. The use of compost-tea has the potential to provide a cost-effective disease suppression program in vegetable (and other) crops that is both environmentally friendly and improves farm worker safety.

This project has demonstrated practical methods for producing compost-tea on farms, which is both simple and effective. Effectiveness was measured in terms of total number of aerobic bacteria per ml, in combination with a low human pathogen level in the finished compost-tea. The main limitation of farm-based production is monitoring and ensuring compost-tea quality and resulting effectiveness.

During the course of this work it became obvious that there is a lack of local information on how to grow "clean" vegetable crops in Australia. There is a need for government and grower associations to support growers in producing "clean" vegetable crops.

This project has raised several issues that need to be satisfied if Australia's vegetable growers are to participate in the growing demand for "clean" food. Specifically these can be summarised as:

- Testing biological disease suppression systems based on using compost-tea on vegetable crops in the field
- Reviewing the packaging, storage and transport issues that ensure the viability of compost-tea from production to farm use
- Explore ways to encourage growers to adopt biological farming techniques for the production of "clean" vegetables.

2. Technical Summary

There is now a significant international demand from consumers for fruit and vegetables grown using environmentally sensitive methods. This demand for "clean" food is reportedly growing faster than any other segment in the food industry.

Environmentally sensitive forms of agriculture are being restricted in Australia by, amongst other factors, the availability of cost-effective inputs for growers and understanding of alternative vegetable production techniques. The use of compost-tea has the potential to provide a cost-effective disease suppression system that is both environmentally friendly and improves farm worker safety.

There is very little scientific research on the production and effectiveness of compost teas in agriculture, particularly in Australia, with the majority of knowledge residing with growers (tea users and producers) and commercial compost and manure tea producers in Europe and North America.

Compost-tea has been shown to be effective against a range of diseases including, but not restricted to:

- Powdery mildew *(Uncinula necator)* in grapes; Weltzien, 1989
- Downy mildew *(Plasmopara viticola)* in grapes; Weltzien, 1986, 1989
- *Botrytis cinerea in* grapes, tomato, pepper; Elad and Shtienberg, 1994

The benefits of compost-tea are due to suppression of leaf fungal disease by coating the leaf with a live microbial barrier, which prevents attack from fungal pathogens. The mode of action (adapted from Brinton, 1995) of compost-tea has been suggested to be:

- Induced plant resistance to disease (similar to vaccination in animals)
- Inhibition of spore germination, and/or
- Antagonism and direct competition with pathogens

This project demonstrated practical methods for producing individual farm volumes of ready-to-use compost-tea, which is both simple to make and effective.

Compost-tea was produced by spraying water over high quality agricultural compost and collecting the leachate. This process extracted the microbes and nutrients from the compost and some of the extracts were treated with molasses to increase microbial numbers.

Effectiveness of the tea was measured in terms of total aerobic bacteria plate-count, which must be above 10^6 per ml (Brinton, 2000; personal communication). All tea produced reached the minimum plate-count required, although inconsistent results were obtained when molasses was added as a food source in an attempt to increase microbe numbers.

A HACCP analysis was also conducted to help ensure low levels of human pathogens in the finished compost-tea.

This project has raised several issues that need to be satisfied if Australia's vegetable growers are to participate in the growing demand for "clean" food. Specifically these can be summarised as:

- Testing biological disease suppression systems based on using compost-tea on vegetable crops in the field
- Reviewing the packaging, storage and transport issues that ensure the viability of compost-tea from production to farm use
- Explore ways to encourage growers to adopt biological farming techniques for the production of "clean" vegetables.

3. Introduction

Australian vegetable growers have been very slow to experiment with biological (organic) farming systems when compared to the proportion of land converted to organic growing methods in some European countries and the USA. Farmers in these countries are responding to the consumer demand for "clean" food and encouragement from governments to convert land to certified organic farming methods. This is important for Australian vegetable growers, as we need to be aware of trends in our major export markets and how to produce vegetables to the new standards.

Given the right farm inputs and knowledge of biological farming techniques, Australian farmers have the ability to produce vegetable crops under large-scale conditions without the using chemical fertilisers or sprays.

Compost-tea is one such input used in biological control of fungal diseases that is cost-effective and one that Australian farmers do not yet have access to. The presence of high quality compost in some states of Australia now makes it possible for "tea" to be made and used in all types of farming pursuits.

The aim of this project is to develop an understanding of farm-based production of compost-tea and the benefits of its use in vegetable crop production systems. As a result of this project, farmers will have knowledge of the benefits of using compost-tea and how to produce it on an individual farm-scale. This biological product can then be incorporated into growers programs reducing reliance on chemical solutions to fungal disease problems.

The project comprised four distinct activities that included:

- A literature review
- A study tour to USA
- Constructing a pilot plant for compost-tea production
- Conducting a HACCP analysis for compost-tea production

Each of these is outlined, followed by a discussion and recommendations from this project.

4. Literature Review

The research papers cited in this review are from Japan, Israel, Germany and the United States. The lack of local information indicates that the development and prophylactic use of compost-tea (a watery extract of mature compost) against foliar pathogens, and as an inoculant for restoring or enhancing soil micro-flora, is in its infancy in Australia.

The production and use of compost and manure teas date back to Egyptian, Greek and Roman times when a sack or bag containing compost was suspended in a drum of water (Ingham and Alms, 2000). However, the earliest reports on disease suppression aspects of compost and compost teas came through organic and biodynamic farming communities in 1924 (Brinton, 1995). Research reviews indicate that compost tea use against foliar pathogens has only recently become a subject for systematic investigation (Weltzien, 1991;

Brinton, 1995; ATTRA, 1998). Kai et al (1990) reported on the potential for using teas against soil borne disease.

In the last 50 years agriculture has become increasingly dependent on chemical control of fungal diseases. Kuc and Strobel (1992) suggested that the productivity, profitability and competitiveness of agriculture must increase at the same time that pesticides used in plant production must decrease. Compost teas may help us balance these conflicting demands of modern agriculture by decreasing the amount of pesticide used, or in an ideal situation, eliminating it altogether. Weltzien (1989) saw the potential for developing compost tea into an economic form of disease control for plant leaf pathogens in field conditions.

The mode of action, and the effectiveness of compost teas, has been the subject of several reviews that differ in their view of the mode of action of the tea and ideal extraction times for the compost (Weltzien, 1989; Elad and Schtienberg, 1994).

4.1 Mode of Action

The modes of action of compost extracts against pathogens were summarised by Brinton (1995) as:

- Induced resistance against disease
- Inhibition of spore germination
- Antagonism and competition with pathogens.

It is possible that all three modes are working in biological disease suppression systems that rely on diversity to provide the stability of the system.

According to Brinton (1995) compost tea is most useful where fungal disease begins and spreads from leaf and stem surfaces. The tea influences the phyllosphere by coating it with live bacteria. Brinton found that the principle agents in compost teas were bacteria, which included *Bacillus, Pseudomonas, Penicillium,* and *Trichoderma.* Chemicals produced by *Pseudomonas spp* had a suppressive effect on other organisms.

Weltzien (1989) considered that the effect of compost tea was due to its microbial nature because sterilised or micron filtered extracts had little if any impact on plant disease. A later study by Weltzien (1992) demonstrated that sterile extracts from short fermentations did not inhibit *Botrytis cinerea* but after 16 days of fermentation had the same inhibitory capacity as non-filtered controls. He suggested this could be due to the effect of inhibitory compounds that accumulated while the compost was fermenting. Elad and Schtienberg (1994) found that pasteurization of extracts did not always nullify their effectiveness and pasteurized compost extracts from 14-day fermentation controlled grey mould.

4.2 Effectiveness in Suppressing Disease

Fungal pathogen control by compost tea has been reported at similar levels to that of conventional fungicides. Weltzien (1991) summarised research where cattle manure compost tea had similar efficacy to the fungicide dichlofluanid applied prophylactically to bean (*Phaseolus*) leaves. In the same work, *Botrytis* strains resistant to dichlofuanid were fully suppressed by two different compost extracts, one based on horse and the other on cattle manure. The latter extract had curative effects equal to procymidon when used after infection and observed for 7 days.

Compost tea has been shown to reduce the incidence of *Botrytis cinerea* on tomato and pepper leaves and on grape berries reared in growth chambers (Elad and Schtienberg, 1994). The teas were made from cattle manure, cattle/chicken manure combination, and grape-marc – with extraction times of 4 hours, 1week and 2 weeks. All three extracts were effective against *Botrytis* on the three crops when applied after 2 weeks of extraction. Reduced extraction times (4 hours and 1 week) resulted in significant reduction of disease levels but results varied between compost types and crops. In the same paper, Elad and Schtienberg claimed effective disease control with extracts made from a fermentation lasting more than 10 days.

Weekly sprays of compost extracts were applied to greenhouse tomatoes giving a 30 and 37% reduction in grey mould incidence, on two different sampling dates, where severe leaf mould (*Botrytis cinerea*) was evident (Elad and Schtienberg, 1994). A commercial fungicide (vinclozolin) however, was significantly more effective in the same situation. In the same study a cattle manure compost tea partially controlled a severe powdery mildew (*Leveillula taurica*) outbreak on tomatoes.

Weltzien (1990) noted that the efficacy of compost tea could be increased by isolating active microorganisms from the extract, multiplying them in pure culture and then adding them back to the compost tea. Elad and Schtienberg (1994) also noted that compost tea made with extra nutrients to stimulate microbial growth tended to be more effective, but not significantly so, when compared with a regular compost extract used to suppress grey mould on tomato and pepper plants reared in growth chambers.

Whilst this review is focussed on foliar disease suppression there is information regarding the use of compost teas in suppression of soil borne disease. Kai et al (1990) found that an extract from hemlock bark compost suppressed *Fusarium oxysporum, Gibberella zeae, Helminthosporium sigmoideum* and *Glomerella singulata* in disk-diffusion studies but was not effective against yeast and procaryotic organisms.

There appears to be no published method of effectively assessing compost teas, however there is at least one commercial laboratory that assesses the effectiveness of teas prior to use (Ingham, 2000 pers. com.). As the quality of compost tea can be highly variable, there is a need to measure the effectiveness of compost teas before they are applied. Brinton (2000, pers. com.) stated that the total number of aerobic and anaerobic bacteria in an effective compost tea should be a minimum of 10^6 per ml. This is significant when assessing research in this area as most researchers have had no direct way of measuring the quality of the tea, other than by effectiveness against disease.

Diseases shown to be suppressed by compost tea
(Table adapted from ATTRA, 1998)

Disease	**Crop**	**Reference**
Late blight *(Phytophthora infestans)*	Potato, tomato	Weltzien, 1990
Botrytis cinerea	Beans, strawberries	Weltzien, 1990
Fusarium oxysporum	*	Kai et al, 1990
Downy mildew *(Plasmopara viticola)*	Grapes	Weltzien, 1986, 1989
Powdery mildew *(Uncinula necator)*	Grapes	Weltzien, 1989
Powdery mildew *(Sphaerotheca fuliginea)*	Cucumbers	Weltzien, 1989
Botrytis cinerea	Grapes, tomato, pepper	Elad and Shtienberg, 1994
Apple scab *(Venturia conidia)*	Apples	Cronin and Andrews, 1996

*Disk-diffusion study measuring zones of inhibition on agar extracts.

4.3 Tea Extraction Process

Compost teas are made by using water to extract the nutrients and microbes from the compost. The tea is aerated by mixing or bubbling air through it for 1 -16 days to increase microbial numbers. The microbes can be fed using different ingredients, but more work is required to understand why additives work in certain situations and not in others (Ingham and Alms; 2000). Elad and Schtienberg (1994) found that adding nutrient broth or agar (Difco) to the fermentation stage did not usually improve disease control. Most researchers appear to have favoured a simple "bag in a barrel" extraction process and have avoided adding any additives to stimulate microbial growth.

Weltzien (1991) outlined the compost-tea extraction process as follows:

Untreated Compost
1 part

Untreated tap water
5-10 parts

Mix in container of volume
5-5,000L

↓

Extraction time 5-10days

↓

Filtration

↓

Applied to plants through
conventional spraying equipment

Extraction times and temperatures have been shown to influence the effectiveness of compost teas. Weltzien (1988) found that teas extracted after 7-14 days provided better results than those extracted after 1-3 days. Water temperature during the extraction process must range between 15 and 25^{0}C (Trankner, 1992). The compost to water ratio was varied from 1:3 to 1:10 without any loss of activity on *Phytophthora infestans* infection of detached tomato leaves, but at 1:50 there was an apparent loss of effectiveness (Weltzien, 1990). Weltzien also noted that there was little difference in effectiveness between composts based on different animal manure.

5. Study Tour

The Study Tour was designed, on a general level, for gathering information to improve Australian knowledge of cleaner vegetable production techniques and, specifically, to investigate the practical aspects of compost-tea production and it's use in growing vegetables. This was achieved by visiting farmers who were using and making compost/manure teas and visiting two commercial manufacturers of tea products in California.

The results of the tour can be split into two main areas – Compost tea production and compost tea use in vegetable production.

5.1 Compost-tea Production

Compost-tea was produced in two basic ways. The first method was a very simple extract of compost in water at room temperature. The duration of production varied, but was normally about 24 hours in on-farm methods. The second method, by commercial manufacturers, had a much longer production period. The process consisted of feeding the microbes (the microbial feed ingredients were not disclosed other than one component which was a sugar based material, probably molasses) and taking the extracted liquid through a controlled fermentation process. The process was particularly important in the manure-based products where the manufacturer was interested in controlling pathogens from the untreated manure.

It appeared that the manure-based product served the same purpose as the compost-tea but required greater capital and skill levels to ensure a quality product and low human pathogen levels. It was obviously not a farm based option and as a result, manure tea was dropped as a separate component of this project, with the focus being on compost-tea for the balance of the work completed.

Manure based teas have a retail price of US $1.60/gal and the commercial compost teas were US $0.85-1.85/gal depending on volume (ie 20L containers to tanker loads).

It was generally accepted that is easy for farmers to produce a short steep (24-hour) compost-tea for use on their crops. They were convinced of the need and the value of using this type of material as a foliar spray even though commercial producers believed in longer "fermentation" times to build up the strength (microbial activity) of the product. This difference in production techniques may be acceptable because of the immediate use by farmers of their own product and the obvious delay in application and possible reduced effectiveness that may occur with the delayed application of a commercially produced material.

5.2 Tea Use in Vegetable Production

Several high profile vegetable growers who were visited during this tour used compost tea as part of their program. These growers included Grimway's organic carrot production (7,200 acres certified organic, using teas), Cal Organic Farms (6,000 acres, using teas) and Boswell's (using biological techniques) in a tomato crop. Teas were generally used as part of a biological farming program, either conventional or organic, and applied as foliar sprays or as soil drenches.

Application rates of compost tea as a foliar spray were 10-20L/ha and applied undiluted through regular spraying equipment. There was little run-off onto the soil with this method, the main emphasis being on leaf coverage and fungal disease control. Growers repeated the tea applications every 1 to 2 weeks during critical times during the crop life.

When applied as a soil drench, compost teas were used at much higher rates, e.g. 600-1,000L/ha to stimulate soil microbial activity in cooler months. Quite often this was applied through regular spraying equipment to the leaves and soil but to a level where there was significant run-off onto the soil. Fungal disease control was still achieved with this system. If irrigation equipment was used then little fungal disease prevention was expected.

The objective of soil drenching with compost teas is to boost microbial activity in soils, particularly in colder months. This has the dual impact of increasing the availability of soil nutrients and suppressing soil diseases.

6. Compost-Tea Pilot Production (Farm-scale tea production)

The production trial included the establishment of a pilot "tea" production facility designed to extract the nutrients and microbial life from compost with water and build aerobic bacteria numbers to a point that is sufficient to suppress fungal disease in vegetables.

The review of literature, the study tour and subsequent communication with people visited on the tour revealed a need to obtain minimum aerobic bacterial numbers (total plate count) of 10^6. There is a distinct lack of information about this issue that is freely available and not considered commercially sensitive by the Californian producers.

6.1 Materials and Methods

Two different aeration methods were used during production the first using pumped water to aerate the tea and the second bubbling air through the tea to facilitate aeration. In both systems, the tea was produced both with and without molasses as a food source.

6.1.1 Pumped Water Aeration

a) Materials

2 x 4,500L tanks (open top)
2 x 60L bags (made from shade cloth)
2 x Davy Pumps (XF 171)
2 x 60L high quality agricultural compost made from pig manure and straw.
3L molasses
PVC pipes (25mm) and spray nozzles

b) Method

Each tank was set up independently with it's own pump so that it re-circulated water through a firefighter spray nozzle and at the same time through an agitating pipe.

500L of water was added to each tank and then sprayed continuously over the compost filled bags (one in each tank). After 24 hours the compost bags were removed and molasses was added to one tank at the rate of 3L of molasses to 500L of tea extract to provide a food source for microbes and increase their population numbers. The second tank had nothing added to it. The watery extract was then pumped (re-circulated) for a total of 14 days.

Water was sampled before adding the compost and the extract was sampled at Day 1 (when compost was removed), Day 7 and Day 14. Both the water and extract were tested for microbial activity, including pathogens (thermo-tolerant coliforms, *Salmonella sp*) and total aerobic plate-count.

6.1.2 Pumped Air Aeration

a) Materials

1 x 4,500L tank (open top)
2 x 1,000L tanks (closed top)
1 x compost bag (made from shade cloth)
1 x compressor with oil filter (to remove oil from air)
1 x Davy Pump (XF 171)
120L high quality agricultural compost made from ground green waste and poultry manure
3L molasses
13mm Poly tube and fittings

b) Method

1,000L of water was added to a 4,500L tank and then sprayed continuously over the compost filled bag for 24 hours using the same method as in Section 5.1.1 above.

After 24 hours the compost bag was removed and the resulting extract was split evenly between each of the 1,000L tanks. Molasses was added to one tank at the rate of 3L of molasses to 500L of extract to provide a food source for microbes and increase their population numbers. The second tank 1,000L had nothing added to it.

Each 1,000L tank was connected to the compressor using perforated black poly tube so that air was bubbled evenly through the water extract continuously for a total of 20 days. There was no other method of agitation of the compost-tea.

Water was sampled before adding the compost and the tea was sampled at Day 1 (when compost was removed), Day 6, Day 13 and Day 20. Both the water and extract were tested for microbial activity, including pathogens (thermo-tolerant coliforms, *Salmonella sp*) and total aerobic plate count.

6.2 Results

Results of microbial analysis for total aerobic plate count, *Salmonella* and thermo-tolerant coliform levels are as follows:

a) Pumped Water Aeration

Treatment	Total Aerobes per ml	Thermo-tolerant coliforms per 100ml	Salmonella per litre
Water – Both Molasses And No Molasses	31,000	2	0
Tea 1 day – Molasses	1,500,000	27	0
- No Molasses	5,600,000	1,600	0
Tea 7 day – Molasses	2,700,000,000	3	0
- No Molasses	7,650,000,000	130	0
Tea 14 day – Molasses	16,000,000	23	0
- No Molasses	300,000	225	0

In this trial (pumped water aeration) the results from feeding microbes with molasses were inconclusive with the no molasses tank having higher aerobic bacteria numbers than the molasses tank.

Interestingly, there was a 3 to 4-fold difference in aerobic plate-counts at day 1 with tea made from the same batch of compost. Both tanks had sufficient bacteria numbers at day 1 and 7 although only the molasses tank maintained adequate numbers for 14 days.

It was initially intended to also sample after 21 days, however the water evaporation rate was so high using this method that the trial needed to be conclude after 14 days. Evaporation loss was approx. 60-70% of the initial volume with the water loss in the molasses treatment being slightly higher than the no molasses treatment.

Salmonella numbers were zero throughout the production and thermo-tolerant coliform numbers were very low when compared to compost production standards.

b) Pumped Air Aeration

Treatment	Total Aerobes per ml	Thermo coliforms per 100ml	Salmonella per litre
Water – Both Molasses and No Molasses	7,000	2	0
Tea 1 day – Both Molasses and No Molasses	42,000,000	1,260	0
Tea 6 day – Molasses	50,000,000	1,600	0
- No Molasses	22,000,000	1,600	0
Tea 13 day – Molasses	29,000,000	1,600	0
- No Molasses	4,700,000	225	0
Tea 20 day – Molasses	11,000,000	1,600	0
- No Molasses	770,000	1,600	0

In this second trial the molasses tank consistently had greater numbers of aerobic bacteria than the no molasses tank. In the no molasses tank aerobic plate-counts reduced progressively from day 1 to day 20.

Thermo-tolerant pathogen levels were low (based on levels allowable in compost, <10,000/100ml) and no *Salmonella* was found throughout this stage of the production trial.

7. HACCP Analysis (including pathogen assessment)

As compost-tea will be used as a foliar spray on food crops it was considered necessary to conduct a HACCP assessment on the spread of human pathogens onto food produce and to establish a system to manage this issue.

A HACCP assessment has been conducted focussing on controlling *Salmonella* and thermo-tolerant coliforms during the tea production process.

Potential sources of pathogens were considered to be:

- Compost production
- Water supply – contamination and chlorination level
- Equipment cleanliness – bag, water pump and pipes, tank, aerating pump and pipes
- Sufficient aeration volumes
- Finished product and storage life (without aeration)

7.1 Compost Production
High quality mature (10-12weeks old) compost made via a thermophillic process where compost temperatures reach 55-65^{0}C for 2-3 weeks ensuring no *Salmonella* and very low thermo-tolerant coliform numbers. Low risk item.

7.2 Water Supply
Considered a low risk area. Regular monitoring, once every 3-6 months, of pathogens in water should satisfy concerns over supply. This is particularly so where tea pathogen level is being monitored.

7.3 Equipment Cleaning
Needs to be washed after use and rinsed 2-3 times with clean water prior to re-use. Cleaning fluids need to be circulated through tanks, pumps and pipes to maximise effectiveness.

7.4 Sufficient Aeration
The efficiency of aeration and agitation should be measured by the total aerobic bacteria plate counts.

7.5 Finished Product (Compost-tea)
Monitoring of finished product for pathogen levels and the total aerobic bacteria plate counts will ensure the viability of the compost tea and reassure concerns for pathogen content. Total aerobic plate count should be at least 10^6/ml.

8. Discussion

The present dependence on agricultural chemicals, including fungicides, to increase crop yield and quality is contributing to the world's environmental deterioration. The chemicals used can also directly affect the health of workers and local people. Crop production with little or no pesticide use however, can lead to large and unpredictable crop losses.

The literature review and study tour section of this project clearly demonstrated that compost-tea is an exciting, viable alternative to commercial fungicides where, at its best, a farmer can get fungal disease control equivalent to chemical fungicides with the environmental safety of natural biological control. Compost-tea is applied at 10-20L/ha as a foliar spray and 600-1,000L as a soil drench. Combined with the cost (US) of $0.80 - 1.80/gal makes it a cost-effective alternative to commercial fungicides.

Compost-tea is most effective when it is incorporated as part of a system to suppress fungal disease levels in agricultural crops. These systems need to be trialed on vegetable crops in Australia to enable growers to develop knowledge and confidence in this natural and potentially cheap source of fungal disease suppression.

This project also successfully developed an understanding of farm based compost-tea production systems by producing tea on a farm that was already using compost to grow vegetables. Throughout this phase it came apparent that farm based production has limitations in the area of quality control, particularly in terms of monitoring aerobic bacteria numbers and pathogen levels. The need to monitor microbial activity suggests that a commercial producer may better conduct tea production where they can achieve some economies of scale in production and the monitoring of tea quality.

There is a need to develop a simple and consistent method for assessing tea quality prior to field use to ensure tea safety and effectiveness. A lack of quality standard may explain why some researchers have failed to achieve disease control with some compost-teas in some crops. Compost-tea must become a quantifiable and reproducible product in terms of effectiveness, if farmers are to incorporate it into their farming practices. This factor alone suggests that a commercial approach to compost-tea production, similar to the USA, rather than individual farm production is more appropriate.

The reluctance of farmers in Australia to adopt biological farming techniques suggests that it is critical for government and grower organisations to encourage and support farmers in the adoption of environmentally sound farming practices. Not only will this open up opportunities to market "clean" agricultural produce to Australia's export customers, it will help provide a sustainable (economic and environmental) future for an industry that is coming to terms with the problems caused by agriculture during the last 50-100 years.

9. Recommendations

This project has raised several issues that need to be satisfied if Australia's vegetable growers are to participate in the growing demand for "clean" food. Specifically these can be summarised as:

- Testing biological disease suppression systems based on using compost-tea on vegetable crops in the field
- Reviewing the packaging, storage and transport issues that ensure the viability of compost-tea from production to farm use
- Explore ways to encourage growers to adopt biological farming techniques for the production of "clean" vegetables.

10. Acknowledgements

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