Identifying the benefits of composted soil amendments to vegetable production

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Department of Agriculture
Western Australia

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Media summary

A major national project to evaluate the benefits of compost to vegetable production has demonstrated compost consistently increases marketable yield and improves soil quality. Its continued use will build soil nitrogen and carbon, increase soil biological activity and cation exchange capacity, increase water holding capacity, reduce bulk density and stabilise pH. This leads to increased returns and benefits for growers, the environment and the wider community.

When transplanting leafy crops good quality compost has been shown to elevate plant available nitrogen increasing yields and potentially allowing major reductions in applied fertiliser. Root crops were shown to be sensitive to compost quality and yield and quality increases were not as dramatic. To gain the full advantage of using compost on these crops it will be necessary to adjust fertiliser programs to account for the improved soil fertility.

Improved marketable yield and savings in fertiliser alone have been sufficient to return extra dollars particularly on light sandy soils. The greatest benefits arise when its regular use effectively 'bullet proofs' the soil against unanticipated climatic events, irrigation or equipment failure and human error that would otherwise result in loss of potential yield.

This is because compost increases soil organic matter which increases the soils ability to:

- Hold crop available nutrients and water.
- Maintain and improve soil aeration and drainage; and
- Maintain optimal pH and reduce erosion.

One of the most important findings has been the ability of compost to increase the supply of plant available nitrogen and potentially reduce the need for large amounts of inorganic nitrogen. It contains useful quantities of plant available phosphorus, potassium and magnesium and the nitrogen it contains is retained in the soil and is available for future crop use. To achieve full benefits growers will need to incorporate the use of compost into their normal management programs and the report acknowledges that a number of changes and developments are needed before growers will use compost on a large scale.

The findings highlight the potential for compost to contribute to the development of 'best practice' production systems that further improve productivity by making better use of fertiliser, irrigation and pesticides and that produce more consistent, better quality crops with less impact on soil and ground water quality.

The level of improvement in soil and crop performance that can be achieved by using compost will depend on the concentration at which soil carbon reaches equilibrium within the applied management system. The report discusses the need to change management practices to increase soil organic matter levels further and achieve greater potential benefits.

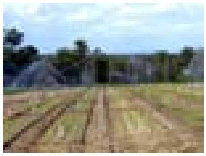
Aspects of compost quality that improve its performance have been identified and made available to the composting industry. However the challenge to the composting industry is to implement quality management that will consistently deliver the quality required for vegetable production.

In the short term, achieving greater use of compost by the vegetable industry relies on reducing its cost. Since the benefits of use extends to the wider community through assisting the beneficial reuse of organic wastes, increasing the proportion of cost borne by the waste producers will provide a mechanism to reduce cost.

Technical summary

This project was established to quantify and promote the benefits of using compost in Australian vegetable production. Vegetable production faces multiple challenges of improving productivity, meeting growing demands for 'safe, clean and green' produce and managing increasing costs and competition while demonstrating sustainable use of soil and water resources.

Both urban communities and agriculture are also being challenged to implement 'zero waste' principals that include environmentally and socially acceptable recycling of their wastes. This project therefore explores the potential for utilising principally organic wastes to the benefit of both agriculture and the wider community.



The research and development program involved fertiliser replacement, production system evaluation and commercial demonstration sites. A series of nutrient replacement trials were established to determine the adjustment in fertiliser program required to accommodate nutrients provided by compost. Replicated split plot experiments were established to evaluate the nitrogen (both WA and Victoria), phosphorus and potassium (WA only) contributions from a commercial urban greenwaste based compost, applied at 0, 30 and 60 m^3/ha. The nutrient under investigation at each trial site was applied at five rates from 0 to 125% of commercial practice and other nutrient requirements were applied in accordance with current best practice. Crop rotation reflected regional commercial practice and where possible combined a root and leafy crop.

The System evaluation trial site in WA allowed comparison of three independently irrigated soil management strategies involving conventional inorganic best practice, compost and compost combined with clay soil amendment. Compost was applied at 30 m^3/ha prior to each crop and the clay content in the clay amended plots was adjusted to 5% in the top 15 cm, prior to trial commencement. In Victoria the focus was on the use of composts made from different feedstocks and the resultant impact on compost quality and performance.

In WA, the sandy soils allowed the installation of lysimeters at both the fertiliser and system sites and combined with electronic tensiometers, allowed detailed monitoring of both irrigation and nutrient management in selected treatments.

In all but one of the 17 trials conducted, yields improvement was indicated. Based on the cheapest fertiliser chemicals, savings in nitrogen, phosphorus and potassium, together with other key nutrients, initially accounted for half of the typical cost of applying compost and with continued use, savings increase to two thirds of the applied cost.

Significant improvements, particularly on the sandy soils, were noted in all soil characteristics measured, including increased soil organic matter, organic nitrogen, biological activity and diversity, cation exchange capacity, volumetric soil moisture along with improved soil pH and reduced bulk density. The addition of clay at the system site further added to both crop and soil performance.

Gross marginal analysis indicated that the use of compost in vegetable production will increase returns. Further when events such as irrigation failure and or unseasonal conditions resulted in crop stress, the improvements to soil performance associated with regular compost use had the potential to produce large increases in crop and therefore returns.

The potential for vegetable production and other horticultural crops to reuse large volumes of reclaimed water from waste water treatment plants creates a need to establish permanent areas or precincts for horticultural production. Apart from challenging the current planning process of continuous urbanisation, the protection of groundwater quality within these precincts will require changes to the current farming system. Combining the reuse of organic wastes to improve soil organic matter and soil performance with the adoption of better management will significantly increase the level of groundwater protection that can be achieved.

Despite the demonstrated improvement in returns, growth in the use of compost in vegetable production continues to be limited. Results at commercial demonstration sites have also generally been positive, but in reality the increases achieved have not been sufficient to overcome:

- cost and a reluctance to alter existing management practices;
- difficulties with making adjustments to fertiliser program; and
- requirements for storing and spreading compost and growers' limited experience with its successful use coupled to either first or second hand experiences with poor quality compost.

Results from the PhD program at the University of Western Australia confirmed that compost makes a significantly greater contribution to the development of soil organic matter than poultry manure. However, the reality is that while there is unrestricted access to low cost raw manures the higher cost and lower nitrogen availability of compost will significantly limit its use by most growers.

Progress is being made in developing suitable application equipment and positive results associated with compost use in an increasing range of crops are accumulating. The current national Compost Roadmap Project, with a focus on developing agricultural compost markets, will assist and potential changes to policies governing the application of organics to land will address some of the competitive inequities that currently reduce compost's competitiveness.

The mobility of inorganic nitrogen in all soils and its impact on groundwater quality is a major challenge for vegetable production. While losses will be reduced by further improving fertiliser and irrigation practices, the use of compost will increase and maintain soil nitrogen and organic matter and provide significant additional capacity to manage nitrogen loss and to use less nitrogen.

Greater research and development focus on 'Carbon based vegetable production' to further increase soil organic matter levels will maximise the potential to reduce nitrogen, irrigation and pesticide usage.

Work to develop these systems will usefully integrate aspects of cover cropping, permanent bed production (Rogers 2002) and possibly sub-surface irrigation with compost use to develop lower input, high performance production systems that better meet the combined needs of greater productivity, better resource protection and the production of safe healthy fresh food.

Introduction

The aim of this project and previous work undertaken by the Department of Agriculture, Western Australia has and continues to be the development of:

- Productive vegetable (horticultural) production based on using compost to build and maintain soil organic matter; and
- These industries as a sustainable market for the reuse of organic wastes from agricultural and urban sources.

This project followed on from a one year project funded by Horticulture Australia, then HRDC, VG 98079 ‘Soil amendments to improve vegetable production on sandy soils’ (Paulin 1999), and was the outcome of a national workshop in Adelaide in 1998. At this workshop, participants divided into two groups that worked on the:

- Use of compost in horticulture – resulting in this project; and
- Soil management regimes based on rotation and cover cropping – resulting in the project VG 98050 ‘Development of a sustainable integrated permanent bed system for vegetable production including sub-surface irrigation extension’ by Gordon Rogers *et al*. (Rogers 2002).

The project ‘Developing productive vegetable production based on the use of composted soil amendments’ commenced in 2000/01. It had three components that were conducted in Western Australia, Victoria and at the University of Western Australia:

- Quantifying the nutritional benefits of composted soil amendments in terms of its contributions to crop requirements for nitrogen, phosphorus and potassium – Fertiliser Replacement Trials.
- Identifying elements of a production system that could maximise the economic benefits of using these materials in vegetable production – System trials; and
- Quantify potential improvements to crop quality and performance – all trials and grower demonstrations.

In Western Australia, the major component of the project, work was conducted on light sandy soils.

In Victoria a project team lead by Kevin Wilkinson carried out a reduced but similar program on heavy soils at the Knoxfield research site and on grower properties at Werribee.

The project funded a PhD studentship at the University of Western Australia to investigate aspects of biological activity, soil health and fertility associated with the use of composted soil amendment in vegetable production. The studentship was awarded to Tamara Flavel and while focussing on the coarse sands in Western Australia, elements of the work were carried on heavy soils at the Victorian Knoxfield site.

The project acknowledged the potential for soil organic matter to contribute to productive vegetable production in a number of ways and sought to quantify them in order to encourage the use of compost in commercial vegetable production. While the focusing on improved productivity in terms of marketable yield and fertiliser savings, the production system element of the Western Australian work also investigated potential irrigation savings.

There is extensive literature on compost, its production and use and this was reviewed when the Department of Agriculture, WA commissioned the study by Tingay @ Associates (Tingay 1997). The report titled ‘Potential use of soil amendments in horticulture’, underpinned the commencement of investigations into how compost could be used in horticulture to improve productivity and provide a sustainable market for the reuse of organic wastes. Further reviews were conducted in conjunction with this and the previous HRDC funded project submissions.

While supporting the potential for compost to improve most if not all aspects of vegetable production, these studies highlighted the need to investigate and quantify within a local context, the range of benefits and to consider management changes that could maximise these benefits. In addition to quantifying benefits in terms of crop production and fertiliser use, the project was also established to:

- Further develop our understanding of critical compost quality requirements.
- Quantify improvements to irrigation use.
- Identify improvement to soil performance, health and fertility; and
- Contribute to economically, environmentally and socially sustainable outcomes for vegetable production.

Growing environmental concerns associated with vegetable production in particular arise from its intensive management and continuous cropping, frequent proximity to estuaries and other environmentally sensitive areas, its extensive use of irrigation that often utilises unconfined aquifers for self irrigation and the nature of soils used (Paulin *et al*. 1995). While the nutrient concerns initially focussed on phosphorus, nitrogen has now become the main focus.

Vegetable production on the sandy soils of the Swan coastal Plain in Western Australia utilise very high levels of nitrogen fertilisers and frequently applying 300 and 400 kg per ha per crop. With crop recovery rarely better than 25% and between two to three crops per year, losses on nitrogen to ground water are significant.

It is increasingly acknowledged that soil organic matter is capable of making a significant contribution to the nitrogen requirements of vegetables and that for this to become a reality, more emphasis on building soil organic matter levels is necessary.

Composting is an essential step in the process of building and maintaining soil organic matter levels because it provides a mechanism for managing risks of introducing disease, weeds and pests as well as other contaminants that are inevitably associated with organic wastes. The composting process typically requires blending of different feedstocks for best process management and this also provides opportunity to manage heavy metal and other contaminants by dilution as well as mechanical means.

Organic materials typically comprise 50 to 60% of the total waste stream and their impact on greenhouse gas production, mainly methane and groundwater pollution emerged as major concerns. Recently the national consulting company, Noland ITU (August 2004) released a statement that the annual environmental cost of landfill associated with major Australian cities is an estimated $670m and that this is over twice their estimate of the National cost of salinity.

Outcomes from these concerns have resulted in various landfill reduction targets (in Western Australia a 50% reduction by 2000 was set) and from the outset, agriculture was recognised as a major potential market for the organic waste component.

However despite progress in some market sectors, most diversion targets proved to be unrealistic and around Australia these targets have been replaced with the concept of 'Zero Waste'. In Western Australia; the States Strategic Direction for Waste Management' released in August 2003 has endorsed a strategy that will work towards 'Zero Waste' by 2020.

An important component of the zero waste has been the general agreement on a Waste Management hierarchy based on principals of avoid, minimise, recycle and energy recovery as options with diminishing priority and disposal or land filling being considered the option of last resort. This hierarchy is summarised in Figure 1 and in this framework, energy recovery as well as landfill or disposal represent the failure to achieve zero waste.

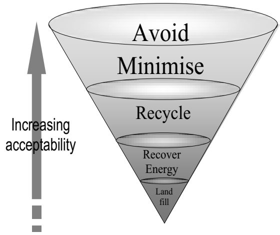


Figure 1. Hierarchy of acceptability for principal mechanisms of waste management.

Recycling organic waste to build soil organic matter has the potential to improve agricultural production and soil performance, to address organic waste management issues, and to better manage environmental and social concerns associated with agriculture.

SECTION 7 – TECHNOLOGY TRANSFER AND COMMUNICATION

Introduction

The aim of the projects technology transfer program was to promote identified benefits of using compost in vegetable production on light and heavy soils, and to develop and promote awareness of the requirements of vegetable production amongst the compost industry and the waste management industry.

The project's outputs are underpinned by the communication plan that was completed in February 2001. The communication plan focused on the production of extension materials (e.g. articles in industry magazines, fact sheets), presentations to the composting and vegetable industries at field days and meetings and the provision of advice to compost producers and growers. Building grower confidence in the use of compost has always been an important aim of these activities.

The target audience has been vegetable growers, compost producers and the organic waste management industry, and the key messages have been delivered via grower sites, media articles, field days, grower meetings, seminars and published material. This has included progressive results as the benefits of composted soil amendments to vegetable production have been identified. These have included:

- Improvement to productivity by increasing marketable yield and reducing fertiliser as well as potentially, irrigation and pesticide requirements.
- Critical quality requirements for vegetable production and the need to produce compost using auditable quality management programs.
- Compost's role in developing soil organic matter in vegetable production that can result in improved soil conditions and increased crop performance from improved soil quality, reduced soil erosion and improved efficiency of fertiliser, irrigation and potentially pesticide.
- Potential to address environmental issues associated with vegetable production including nutrient, and particularly nitrate nitrogen loss to ground water.
- Strategies for maximising benefits of compost use.
- Contributions to "safe, clean food production by reducing fertiliser, irrigation and in the longer term, pesticide use"; and
- The importance of the waste collection process delivering source separated organic materials to the compost industry in order to minimise contaminant risks and maximise potential compost quality.

~~Methods~~

~~Key stakeholders have been encouraged to contribute to management of the project. In Western Australia a project management group comprising three growers, two compost producers, the Vegetable Industry Development Officer, the PhD student based at the University of WA the state Horticulture Australia representative and the principal project officers that met al least twice a year.~~

Interstate coordination was managed with six monthly meetings between the state project teams and a senior HAL program representative. These alternated between Perth and Melbourne for the first two years of the project and subsequently, opportunities were available to ensure ongoing face to face communication in conjunction with conferences and other events.

The PhD program was managed through regular meetings between the project staff and thesis supervisors at the University of Western Australia.

Vegetable industry communication has been through State Vegetable grower Associations, Industry magazines, Field days, rural press and industry events and Expos. The establishment of several 'Key grower sites' was considered important for:

- promoting and encouraging greater use of compost in the vegetable industry; and
- validating findings from the research program.

The development of information packages was the other key component of the technology transfer process. The elements of this included:

- strategies for using compost and maximising results;
- information on potential benefits including fertiliser savings;
- facts on the production of compost suited to use in vegetable production; and
- options to improve soil organic matter management.

Communication with the Waste Management and the Compost Industry has been the other and arguably at least equally important focus. Recognising that the composting industry is still in its infancy, this has included active involvement and where appropriate, leadership in the development of the organic sector of the Waste Management Industry.

The underlying objective of all communication with the Organic Waste management sector has been to:

- developing and promoting compost quality requirements for vegetable production; and
- promote the requirements for achieving that quality throughout the waste management industry from compost process management and waste collection.

Communication has also targeted tertiary institutions and students involved in vegetable production and soil management. These have included the Soil Science group at University of Western Australia (the project has funded a PhD program that is supervised by this group), the Centre for Organic waste Management at Murdoch University and Gilbert Chandler College (University of Melbourne), Werribee.

Other identified 'groups' have included:

- organic as well as biological farmers associations;
- State waste management bodies/board and EcoRecycle Victoria; and
- key resource management agencies including water commissions, environmental protection and planning.

Every opportunity has been taken to promote the project and its results including the potential benefits and synergies for all sectors of our community that arise from the reuse of organic wastes in vegetable production. This has included presentations at national and international conferences and several interstate events.

Results and discussions

The outputs of the technology transfer program have principally targeted the vegetable and organic waste management industry. They are detailed in the Appendix 7.1 under the headings:

- Media, radio, press, newsletters and magazine articles.
- Vegetable grower communication – field days, tours, expos and displays.
- Other stakeholder meetings and presentations.
- Conferences, seminars, workshops, papers and presentations.
- Planning meetings.

The concept of 'Carbon based production' has developed from the recognition that soil organic matter and the associated recycling of organic materials is the basis for most if not all of the potential benefits from using compost. This has become the basis for a number of national 'roadshow' programs that have targeted growers and the organic recycling industry stakeholders during the life of this project. These included:

- Three seminars in Sydney, Hunter Valley and Orange as part of an Agriculture Action Agenda program held in mid March 2002.
- A series of two seminars and one field day on 'Bullet proofing soils' that promoted the use of compost in vegetable and other forms of horticultural production that were held in Melbourne, Seymour and Tatura in Victoria and to a Seminar in Adelaide during March 2004; and
- Presentation of project findings to the 'Compost – the way to grow' two day seminars that were held in Melbourne and Perth during February and March 2005. CD's of the various programs are available from the Waste Management Association from admin@wmaa.asn.au.

Vegetable industry

Initial communication focussed on promoting the project and its objectives to the vegetable industry through the media and various events. These included making presentation to industry field days such as carrots and lettuce programs at the Medina Research Station, Because of a combinations of clashes with other events, difficulties with coordinating the timing with suitable crop development stages and perceptions, real or otherwise that there would be insufficient interest, specific events for vegetable growers at either the Medina Research or demonstration sites were not held.

A compost demonstration trial was established at the Werribee Expo in May 2003. The trial was 8 beds wide and 18 metres long and was planted with broccoli after compost was incorporated. Three locally produced composts were included in the trial at 3 different rates, as well as a treatment that did not receive any compost application (control). The trial could have been better located to maximise exposure but nevertheless generated interest amongst some growers. At the trial site a display was also set-up to demonstrate what the compost products looked like on the ground at different rates and what the approximate costs of application were. A display with brochures and posters was also set-up in a tent near the trial site.

A series of fact sheets were prepared for vegetable growers. Growers are sceptical of the many claims that are made of soil amendment products such as composts. The fact sheets were developed to provide growers with enough information to 'demystify' compost and be able to make informed decisions about the value of such products.

A major issue for achieving greater use of compost relates to realising that while the benefits of using compost are all positive, the improvement in returns are usually too small to warrant the changes involved with using it.

There is increasing awareness of the importance of soil health and organic matter management among growers. This has been clearly evident in our small group and one-on-one discussions with growers. It is also emerging as an important strategic issue at the whole of industry level (soil health was listed this year as a priority in the R&D strategies of the vegetable and potato industries). The Environmental Management Systems that are being developed for horticultural industries around Australia will lead to more sustainable practices being adopted by growers, and from our results, they will benefit from including the use of compost.

The development of Environmental Management Systems for horticultural industries around Australia focuses on more sustainable practices being adopted by growers. These outcomes will be improved by including the use of compost.

A half day seminar for vegetable growers in the vegetable growing regions around Perth was attended by around 40 growers in October 2003 and further events will be held when strategies to overcome some of the factors that limit compost use are able to be implemented.

The recent National Compost roadmap project, funded by the Waste Management Association of Australia, various State Environmental Agencies through their waste management bodies including the WA Waste Management Board and EcoRecycle Victoria, and the Commonwealth Government through the Barton Group, was a major event that attracted significant participation from the range of stakeholders targeted. Attendance at these two day conferences held in Brisbane, Sydney, Melbourne, Adelaide and Perth attracted between 75 and 140 delegates at each venue, however in all states, the participation by vegetable growers and farmers was disappointing.

This process will culminate in the release of a strategic market development plan in July 2005 as a 'blueprint' for developing the agricultural, and principally vegetable and other intensive horticultural industry groups as long term sustainable and critically important markets for composted organic wastes from both rural and urban community.

The disappointing attendance by vegetable and other growers needs to be kept within the context of progress to date with recycling/reusing organic wastes. In reality many agricultural wastes are being reused and developing markets for urban organic wastes has been hampered by the lack of appreciation of what is required to develop the horticultural market.

This National 'Compost Roadmap Project' in itself is arguably the first significant acknowledgement that the horticultural and vegetable industries in particular, have a major role to play in driving the reuse of organic wastes to land application.

The current situation with limited growth in the vegetable industries use of compost is hardly surprising, given the time that it has taken the waste management industry to realise this potential, and the reality that the composted products they produce are 'relatively very expensive' compared to the widely available organic wastes, usually animal manure, from agriculture.

Compost use in vegetable production faces significant competition from the current largely uncontrolled use of raw organic materials.

Waste management industry

The project has resulted in the development of a set of quality specifications for compost to be used in vegetable production that are based on the Australian Standards for 'Compost, Soil Conditioners and Mulches', AS 4454–2003.

When green wastes are used as a feedstock for composts destined to be used in the vegetable industry, process management involving passing the compost through a 10 to 12 mm screen before use has also been developed. These specifications are provided in Table 7.1 and the use of a 10 mm screen is preferred.

Table 7.1. Recommended critical analysis values for compost use in vegetable production. Analysis conducted to Australian Standards AS 4454–2003

Measurement	Value	Unit	Comment
Carbon Nitrogen (C/N) ration	< 20	none	For crop available nitrogen.
Nitrogen Drawdown Index (NDI)	> 0.5	none	Lower values likely to compete for crop N.
Organic matter	> 35	% DM	Higher the better.
pH ($CaCl_2$)	5-7.5		Ideally around 7.0.
Electrical conductivity	< 6.0	dS/m	
Toxicity (potting mix test)	> 60	%	Indicates immaturity and possibly anaerobic composting conditions.
Moisture content	> 25	%	Ideally around 40%.
Total Nitrogen	> 1.0	% DM	Generally not greater than 1.7%.
NH_4 + NO_3	> 100	mg/L	Also indicates N availability for crop.
NO_3/NH_4 ratio	> 0.14	(m/L)	High ammonium level indicates immaturity.
Particle size	< 12 mm	Screen mesh	10 mm screen preferred.

The carbon in wood is highly lignified and is therefore more resistant to decomposition in the initial decomposition phase of the composting process. The minimum 10 to 12 mm screening requirement is therefore aimed at removing undecomposed woody material and preventing the compost, or rather the microbes within the compost, from competing with crops for nitrogen during early crop germination and or establishment. Earlier work identified this problem (Paulin *et al*. 2001) and it was also recorded in one of the initial carrot trial at the Medina Nitrogen Replacement trial site.

This project focussed on using composts made from green wastes recognising that in the short term, this was the largest and cleanest organic waste stream available from urban sources. These wastes can also be derived from land clearing activities and with restriction on burning; these are an increasing feedstock for compost manufacture. This waste stream has an even higher content of wood than the typical green waste collected from street verges and council drop off centres and the need to manage potential problems associated with them is even more critical.

The importance of using fine screens was confirmed during the Tour of Californian compost production and utilisation (Paulin 2002) that took place during May 2002 and the use of fine screens has been widely adopted by producers that aim to produce compost for vegetable production.

The Californian tour was unable to attract any vegetable grower participation; however the compost industry participants from all the mainland states witnessed a composting industry that has achieved the highest diversion of urban wastes into horticulture, principally vegetable production, in the developed industrialised world (Paulin 2002 – Report). It also provided opportunity to discuss some of the key aspects of legislation and policies that have underpinned this success.

The Californians have facilitated agricultural reuse of urban organic wastes by:

- *mandating organic landfill diversion targets;*
- *requiring compost producers to demonstrate compliance with minimum health safety standards for disease, pests, weed and heavy metals;*
- *encouraging compost quality through a process of disclosure.*

These factors are discussed in the tour report, and included:

- Imposing substantial financial penalties for not meeting organic waste diversion targets.
- Requiring compost producers to demonstrate compliance with minimum safety standards for disease, pests, weed and other contaminants including heavy metals and a range of bio-toxins; and
- Encouraging participation in quality assurance programs that include a requirement to disclose minimum levels of product information and analysis.

With respect to the composting industry, we have continued to promote best practice compost production. Project members have been actively involved in the development and with carrying out a range of executive roles in Compost Industry groups including Compost Victoria and the Compost Industry Association of Western Australia. More recently a workshop organised in conjunction with the recent WA Waste and Recycle 2004 Conference in Fremantle resulted in the establishment, of a recycled organics group (ROWA, Recycled Organics WA) as a sub-group to the Waste Management Association. With potential membership of all stakeholders involved in the recycling and reuse of organics, this group has much wider stakeholder representation than the previous Compost Industry Association and will continue the affiliation with the National Compost Australia group.

The objective to promote the development of appropriate compost products based on quality requirements of vegetables and other crops has also been served by membership on the Australian Standards Committee for Composts, Soil Conditioners and Mulches, AS4454 (K. Wilkinson). Through this we have had direct influence on the development of the Australian Standard (AS4454), particularly with regard to best practice processing guidelines. Although at the moment it is not a market-driven Standard, we hope to influence development in that direction as more fit-for-purpose products are developed. This will involve the development of guidelines for producing a range of compost products that are suited to different uses, the emphasis being on providing guidance, not specific standards.

Extensive presentations have also been made to all targeted stakeholders including universities, and a number of papers and posters have been presented throughout Australia and overseas to a range of audiences from compost producers and waste management industries, government resource management and planning and researchers in horticulture and soil science.

Appendix 7.1 lists most of the presentations made to stakeholders and to various conferences. Some examples include the presentation of 2 oral papers at the 2002 International Symposium on Composting and Compost Utilisation in Columbus, Ohio in May 2002. One paper focussed on preliminary findings from this project. These results were discussed with the underlying assumption that compost use will be the building block for economically, environmentally and socially sustainable 'carbon based horticulture'. It was noted that composts derived from urban green waste usually require longer processing times than is currently practised, in order to provide consistent short-term benefits to vegetable production. The importance of compost quality and its likely impact on the acceptance of compost in horticultural industries was the subject of the second paper. It showed that green waste compost in Australia is highly variable in quality and argued that the adoption of market-based quality assurance programs was a necessary precursor for achieving consistent performance with compost in horticultural applications.

Products and tools

The project has produced a number of published information products that include:

- A series of four fact sheets on compost for vegetable growers covering 'What is compost; What use is compost; Getting started and Choosing a supplier.
- A draft bulletin on 'Compost production and use in horticulture – this has been regularly updated and has been available since early 2000, as a general source of locally relevant information on producing and using compost. It will be finalised and published as an official bulletin on completion of this report.
- A 'Note on Compost use in Horticulture' produced as a single page handout for industry expos.
- A discussion paper 'Compost production for agricultural use – issues for the developing recycled organics industry' has been finalised and reflects the considerations of this project and other work with a range of horticultural crops.

These are attached to this report.

When completed, the information compiled and various products will be embedded into a 'Compost Page on the Department of Agriculture's web site. With further development to make them user friendly, several excel based spreadsheets will be made available for use by growers, consultants and the compost industry. These potentially include:

- A vegetable fertiliser model – a tool for adjusting grower fertiliser programs to accommodate the use of composts. It will integrate soil analysis information, cost the use of compost based on fertiliser savings, associated application costs, and other anticipated changes to returns and management costs. It will also enable programs to be compared with established industry best practice.
- Gross margin vegetable crop calculator to compare likely impacts of compost rate and cost together with management cost savings and yield improvements and returns. This model was used to derive Table 9.1 that indicates yield improvements necessary to cover costs of compost application for the crops grown at the System site trials at the Medina Research Station;
- Compost application cost calculator that has application to annual (vegetable) and perennial crops.

SECTION 8 – OVERALL PROJECT DISCUSSION

With the focus on increasing vegetable productivity, the project was established to:

- Quantify benefits and develop strategies for maximising the benefits of compost use to vegetable production; and
- Identify issues that limit the development of vegetable production as a market for composted urban and agricultural wastes.

The benefits of compost include improved marketable yield, savings in fertiliser costs and a range of other savings including reduced irrigation and harvesting costs that are situation dependant. With continued use, a range of improvements to soil quality and fertility contribute to further savings in fertiliser use as well as more consistent reductions in irrigation and potentially, reduced pesticide use. These improvements to soil performance 'bullet proof' against the adverse impacts of management failure and unanticipated climatic events that have the potential to reduce production.

Considerable progress has been made however, achieving greater use of compost in vegetable production is constrained by its cost and in particular, its lack of competitiveness with other organic amendments, namely manures.

The results of this project have been extensively reported and formed the basis of our input to the recently concluded National Compost Roadmap Project that was established to provide a strategic plan for the development of the compost market, primarily in agriculture.

Benefits of compost use to vegetable production

Productivity

The over whelming conclusion from our work is that growers can anticipate positive improvement in marketable yields and reductions in production costs associated with vegetable production. Compost quality is clearly important and to achieve consistent increased returns from using compost, it is important to make adjustments to their fertiliser use.

BENEFITS OF COMPOST

- ***Increased production and crop quality.***
- ***Significantly reducing inputs of fertiliser, irrigation and potentially pesticide use and;***
- ***Maintaining and improving soil and water quality.***

With regular compost use, improved productivity will largely result from the soils increased ability to supply plant available nutrients and moisture, and to reduce periods of stress during the life of the crop.

There are concerns relating to how well compost works with some crops. Leafy vegetable crops, including lettuce and Brassica, respond with greater consistency than root crops such as carrots and potatoes. However our work indicates that all crops will potentially benefit from compost use. Despite the repeated occurrence of poor quality in the compost applied to carrot crops the overall indication was for compost to improve carrot quality.

In order to achieve optimum yield certain crops such as carrots and potatoes appear to have a greater requirement for a "balance" to be maintained between the major nutrients. With this project, and with most of our compost work, it was not possible to adequately adjust fertiliser rates for the nutrients supplied by compost and our results with carrots and possibly potatoes, indicate that closer attention in keeping, the major nutrients in particular, within reasonable balance is needed. This emphasises the need to adjust fertiliser programs to account for compost supplied nutrients and to monitor soil and plant analysis.

Fertiliser savings and compost contributions to crop nutrition

> **Fertiliser savings will cover at least ONE HALF to TWO THIRDS of the cost of applying compost.**

The fertiliser value of compost based on low cost common fertilisers such as urea, superphosphate and potassium sulphate will range from \$20 with the initial application to over \$30/m^3 with continued use. Using typical costs for compost and its contractor application rates, these potential savings can meet 50% to 65% of the applied cost of premium quality compost within a 50 to 100 km of the compost producer.

Estimated fertiliser cost savings associated with compost use initially include allowance for 40 per cent of its phosphorus content to be equivalent to superphosphate (Figure 1.28) and 100 per cent of its potassium to be plant available.

> **PHOSPHORUS**
> **Initially 40% of the phosphorus content of compost is equivalent to superphosphate and Standard Colwell phosphorus test effectively estimates crop phosphorus requirements in compost amended soils.**

With continued application, all of the phosphorus from compost will contribute to the soil phosphorus pool and adjustments in fertiliser phosphorus requirements will be achieved through standard soil testing procedures. This is because the standard Colwell procedure based on bicarbonate extraction, that is used in Western Australia to estimate plant available phosphorus, continues to provide reliable estimates of sufficiency when soils are amended with compost (Figure 1.27).

> **POTASSIUM**
> **Potassium from compost is 100% available from the initial application; and within three applications, improvements to cation exchange capacity results in a 20% reduction in potassium requirement.**

Potassium use efficiency increases and over three compost applications, potash requirement was reduced by 20 per cent (Figure 1.34), this saving presumably resulting from the soils increased cation exchange capacity. While not directly measured, our results also indicate that the magnesium content of compost is also 100% crop available.

> **NITROGEN**
> **Soil nitrogen reserves increase with continued compost use and with appropriate compost quality, result in significant supply of soluble nitrogen that have the potentially to reduce nitrogen requirements by up to 50% on sands.**

Nitrogen is a complex issue because its availability is influenced more by compost quality and possibly biological activity than other major nutrients. Our work suggests that initially very little of the compost nitrogen was available and that over the seven crops at the Nitrogen Replacement site, only 18% was utilised by the crop leached (Table 3.38). However, with the final trial at the nitrogen site, the less mature compost (Compost A) produced significantly higher yields. Presumably as a result of stimulating mineralisation of soil nitrogen reserves. It contributed the equivalent of 300 kg/ha of fertiliser nitrogen to the lettuce crop enabling 95% of maximum yield to be achieved with 267 kg/ha of applied nitrogen compared to 582 kg/ha for the control. It is generally accepted that nitrogen fertiliser application can be reduced by the equivalent of around 20% of the nitrogen contained in an initially application of compost and that this increases to around 30% or more after three to four applications.

The important result of organic nitrogen mineralisation within a healthy ‘fertile’ soil is that plant available nitrogen can be maintained during periods of rainfall that typically leach fertiliser nitrogen out of the crop root zone. A further important issue is that any surplus mineralised nitrogen can be re utilised by soil microbes. In this way, nitrogen losses can be significantly reduced and this process explains why ground water nitrogen levels under organic cropping systems have very low nitrogen levels (less than 10 mg/kg) compared to equivalent 'inorganic' farming systems (48 mg/kg) (Vogtmann presentation 2000).

Soil nutrient reserves are essential for sustained mineralisation. Our work has shown that regular compost application builds substantial nitrogen reserves in the top 30 cm of coarse sands when after five crops at the System site, levels were almost three times those in untreated soil (Table 3.33). Further, soil analysis indicated that levels of nitrate nitrogen in the soil solution, assuming field capacity conditions (10% volumetric soil moisture) was in the order of 200 mg/kg (Table 3.33). This level is the upper range of hydroponic system requirements and indicated compost increased soil nitrogen mineralisation early in the life of the crop. This supports the view that compost use can be used to reduce fertiliser nitrogen requirements and reduce its loss to groundwater. Leachate collections, without benefits from reduced nitrogen application support this (Table 3.40).

These findings suggest that with the continued use of compost further savings in fertiliser and in particular nitrogen use can be achieved, enabling nitrogen use efficiency to be increased and total application substantially reduced over present rates.

A compost maturity index developed in California has demonstrated that a relationship exists between compost quality (maturity) and nitrogen fertility in vegetable production (Buchanan 2002). This work has also shown that the crop nitrogen response is dependent on compost quality/maturity and indicates that the standards developed for compost nitrogen analysis provide a good indicator of its potential performance in vegetable production.

Irrigation savings

The system site allowed treatments to be independently irrigated. Recorded savings have been greatest for the clay plus compost treatment during the cooler Autumn to Spring period when natural rainfall makes a significant contribution to crop water requirements. While the addition of clay has further increased soil moisture holding capacity, results indicate that savings during the summer months when evaporative demand is highest, are considerably smaller. This presumably reflects the coarse nature of the sandy soils used and in particular the limited hydraulic conductivity that prevents crops being grown without daytime application of irrigation.

IRRIGATION

Compost significantly increases soil moisture holding in light sandy soils. While this study suggests that under conventional vegetable management, savings are unlikely to exceed 10% over a 12 month cycle more work is warranted.

Average irrigation savings over a 12 month period estimated from this work are likely to be greater than 20% for the compost plus clay treatment but less than 10% for the compost alone treatment. The automated triggering of irrigation using the same soil moisture tension setting across all treatments could have potentially reduced the indicated savings to irrigation (Table 3.42). More work in this area is warranted.

Soil quality, fertility and health

Our results have consistently identified the importance of soil organic matter in improving all aspects of soil quality and is a compelling reason for placing much greater emphasis on the management of soil organic matter in vegetable production and agriculture in general.

Soil quality: Measurements of soil quality that included Bulk Density, Cation Exchange Capacity, volumetric water holding capacity, pH, Organic Matter (Carbon) and nitrogen levels have all improved significantly with regular additions of compost at both the sandy Western Australian and heavy soil Victorian sites.

In coarse sands, soil carbon levels are known to plateau at low levels while in heavier soils they achieve much higher levels. However even in our coarse soils, significant increases that potentially contribute to carbon reserves and therefore the soils capacity to sustain the populations of microbes, micro fauna and organisms that collectively contribute to soil health, fertility and performance, were recorded.

> **SOIL QUALITY**
> **With regular compost use:**
> - **Bulk density is reduced, improving potential root growth, drainage and infiltration.**
> - **pH is buffered around 7.0**
> - **Cation exchange increases.**
> - **Soil moisture holding increases.**

The intention of investigating the potential for the addition of clay to allow soil carbon to exceed 1.0 per cent and to possibly approach 2.0 per cent was not realised, partly because the initial carbon levels, even by Swan Coastal Plain standards, were very low and secondly because only five crop cycles were completed.

At the conclusion of this project, 200 t/ha of compost was applied to the 'Systems' site as part of continuing work to quantify the longer term benefits of compost use. This will involve continuing production of vegetable crops using 30 m^3/ha over the next 12 to 24 months.

However achieving soil carbon levels that will sustain microbial population dynamics necessary to maintain soil nitrate nitrogen levels and to potentially manage soil pests and diseases are likely to require further changes to management practices that could include:

- Reductions in soil cultivation and the use of equipment that is less damaging to soil microbial populations and their contribution to soil structure.
- Greater emphasis on using safe pesticides and integrated pest management practices.
- Changes to crop rotations and more extensive use of cover crops.

Finally, with light soils in particular, increasing soil carbon above current levels will be critically important for increasing soil moisture holding capacities and their associated hydraulic conductivity to levels where day time irrigation, and the associated large evaporative losses, can be significantly reduced.

> **SOIL FERTILIY**
> - **Without the addition of compost, soil organic matter and carbon levels decline in all soils.**
> - **Compost use results in substantial organic nitrogen reserves and mineralisation has the potential to significantly reduce nitrogen fertiliser requirements.**
> - **Compost use reduces nitrogen leaching.**

Soil fertility is related to crop nutrient supply and includes minor and trace nutrients within which heavy metals are an important consideration. This is because of their potential to impact on soil quality and health, and to harm human, animal and crop health, as well as the environment.

Fertility is intimately related to improving and maintaining soil carbon levels. The major potential outcome from building fertility will be to improve nitrogen fertiliser management through the development of soil nitrogen reserves. Both the Nitrogen Replacement (Figure 1.43) and System trial sites (Figure 3.9 and Table 3.37) in Western Australia and the Nitrogen Replacement trial site in Victoria (Table 2.14) have demonstrated significant improvements in soil nitrogen reserves following compost application. The percentage improvements over control plots are summarised in Table 8.1.

Table 8.1. Comparison of increased soil nitrogen at planting of trials in Western Australia(% db) and Victoria (mg/kg)

Compost rate	Trial site and N°.	Total nitrogen		
		Control	Compost	% Increase
Compost 30 m^3/ha	WA; N Replacement - 7	0.027	0.048	77.8
Compost 60 m^3/ha	WA; N Replacement - 7	0.027	0.065	140.7
Compost 30 m^3/ha	WA; System site – 5	0.013	0.041	192.9
Compost 30 m^3/ha + Clay	WA; System site - 5	0.013	0.056	300.0
Compost 70 m^3/ha	Vic; N Replacement - 4	0.15	0.22	46.7

Soil analysis confirms that variable nitrogen mineralisation had taken place at the Western Australian trial sites. Table 8.2 shows that variation in soil nitrate at planting was a consequence of compost quality and, more specifically maturity ,rather than a result of seasonal conditions (Figure 8.1).

Table 8.2. Comparison of compost nitrogen contents and increased soluble soil nitrogen at commencement of trials in Western Australia

Trial	Compost N content			Available soil N (mg/kg) at planting		
	Total N	$NH_4 + NO_3$	NH_4/NO_3 Ratio	Control	Compost	% Change
N Replacement site (Compost A 30 m^3/ha)						
Crop 1 lettuce	1.3	< 1.0	< 0.1	4.70	5.32	13.2
Crop 2 Carrot	1.3	23	23	3.71	5.01	35.0
Crop 3 lettuce	1.6	89	< 0.1	12.00	13.77	14.8
Crop 4 Carrot	1.2	27	< 0.1	14.92	14.67	-1.7
Crop 5 lettuce	1.4	140	< 0.10	6.55	7.32	11.8
Crop 6 Carrot	1.1	50	> 1.0	8.90	9.78	9.9
Crop 7 lettuce	1.4	110	0.93	6.15	12.35	100.7
System site (Compost 30 m^3/ha)						
S-3 Broccoli	1.5	130	16	3.75	7.00	86.7
S-5 Lettuce	1.6	280	> 280	3.75	13.75	266.7

Note: Soil available nitrogen levels of 12.35 (Crop 7) and 13.75 (S-5) provide a nitrogen concentration of 190 and 265ppm in soil solution, based on 10% volumetric water at field capacity of these coarse sands.

The importance of nitrogen in the soil solution at crop establishment was highlighted in the final Nitrogen replacement trial. Analysis of soil nitrate concentration at planting accounted for 90% of the variation in total lettuce plant weight across the range of nitrogen rates (Figure 1.17) and illustrated the benefit of the additional soluble nitrogen associated with the compost treatments.

This is supported by comparing the analysis of compost nitrogen levels with the levels of plant available nitrogen in soil at planting (Table 8.2). Note that on three occasions, large increases in mineralisation occurred when the compost had adequate levels of inorganic nitrogen (>100 mg/L) in the nitrate form. This relationship between the plant available nitrate nitrogen content of compost and its potential to improve crop yield was identified in Californian compost maturity investigations with vegetables (Buchanan 2002). It was also supported by yield improvements associated with two of the three Western Australian trials where significant mineralisation occurred (Table 8.2).

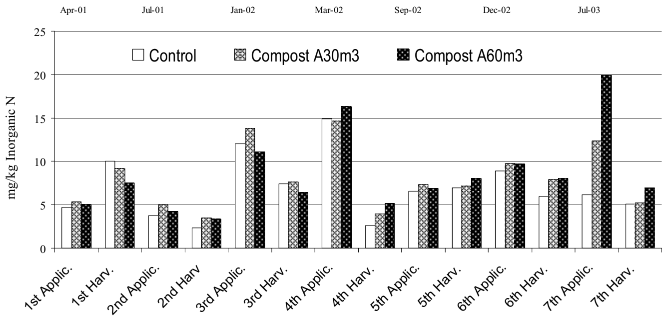


Figure 8.1. Seasonal nitrogen mineralisation at planting and at harvest for the seven trials at the Nitrogen Replacement site from April 2001 to July 2003.

The lack of crop response to compost despite high levels of soil nitrate in the final system trial (S-5) can be explained by the increased frequency of early fertiliser nitrogen adopted for this trial (see discussions page 181). Trial 5 at the Nitrogen Replacement site also demonstrates the importance of compost maturity on mineralisation and nitrate nitrogen. This compost had adequate inorganic nitrogen (140 mg/L) however, it was in the ammonium form indicating that at best, this compost was very immature and did not stimulate soil mineralisation of organic nitrogen.

Soil analysis from the fourth crop at the Victorian Nitrogen replacement site indicated that compost increased total soil nitrogen by 50% but reduced soluble nitrogen by almost 10% (Table 2.14). Although the compost used met most of the specified criteria (Table 2.13), a notable exception was the 0.07 Nitrate to Ammonium nitrogen ration that is below the suggested value of greater than 0.14. This again emphasised the importance of compost quality and its impact on nitrogen mineralisation.

Compost that strongly stimulate Nitrate nitrogen levels in the soil solution are therefore likely to produce the best results in terms of crop performance.

The Western Australian system site demonstrated that in the presence of clay, the nitrogen applied as compost together with some of the fertiliser applied nitrogen was retained (Figure 1.43 and Figure 3.9) and that compost alone reduced nitrogen loss. The percentage of compost nitrogen retained was 148% for compost plus clay and 82% for compost alone (Table 3.38). Despite continued commercial application control plots lost 11% of its soil nitrogen over the 5 crops. Leachate analysis also confirmed that nitrogen leaching, over an 8 month period, was reduced 14% with compost and 26% with the compost plus clay treatment (Table 3.43).

Minor and heavy metal levels were analysed in 12 of the composts used at the Fertiliser replacement and System trial sites in WA (Table 8.3). The only metals of concern were copper and zinc. Eight of the 12 samples would have exceeded the "Biosolids Adjusted Contaminant Concentration" (BACC) for copper and 11 would have exceeded it for zinc.

Table 8.3 Concentration of heavy and minor metals in 12 composts used during the Project

Metal (mg/kg db)	Mean	Min	Max	SD	BACC* Grade C1	Samples exceeding BACC
Arsenic (As)	1.3	0.9	4.0	0.99	20	0
Boron (B)	16	0.1	26.0	7.31		
Cadmium (C)	<1.0	< 1.0	<1.0	0.00	3	0
Chromium (Cr)	6.4	<1.0	12.0	4.01	100	0
Copper (Cu)	92	52.0	190.0	42.53	100	8
Lead (Pb)	7.8	<1.0	16.0	5.62	150	0
Manganese (Mn)	169	69.0	290.0	65.57		
Mercury (Hg)	<1.0	<1.0	<1.0	0.00	1	0
Molybdenum (Mo)	2.7	<1.0	5.8	2.08		
Nickel (Nc)	3.5	0.9	8.5	2.59	60	0
Sodium (Na)(%)	0.21	0.1	0.3	0.03		
Zinc (Zn)	195	80.0	450.0	104.92	200	11

*Contaminant grading, Biosolids Adjusted Contaminant Concentration, "Guidelines for Direct Land Application of Biosolids and Biosolids Products (Department of Health, Perth, WA)". BACC = Mean + SD.

Despite the perceived high concentration of these two elements soil analysis (Mehlich 3 Extraction) after 7 applications of compost plus additional fertiliser additions of copper and zinc, recorded only a small increase for zinc and a slight decrease for copper in compost treated plots. Increases were recorded for the essential nutrients boron, calcium, magnesium and sulphur. Decreases were recorded for Cadmium and Molybdenum (Table 8.4).

Table 8.4 Soil concentration of selected metals after 7 applications of Compost (N Site)

Metal (mg/kg db)	Control	30 m^3/ha	60 m^3/ha	Grade C1**
Arsenic (As)	n/a			20
Boron (B)	0.10a*	0.34b	0.48c	
Cadmium (C)	0.03a	0.02b	0.02b	1
Calcium	625a	1250b	1750c	
Cobalt	0.052a	0.049a	0.048a	
Chromium (Cr)	n/a			100 - 400
Copper (Cu)	6.4a	5.8b	4.8c	100 - 200
Iron (Fe)	102a	108a	112a	
Potassium (K)	42a	48a	57a	
Lead (Pb)	n/a			150 - 300
Magnesium (Mg)	26a	63b	97c	
Manganese (Mn)	16a	17a	16a	
Mercury (Hg)	n/a			1
Molybdenum (Mo)	0.10a	0.07b	0.05b	
Nickel (Nc)	0.25a	0.15b	0.13b	60
Sodium (Na)	3.0a	5.0b	6.8b	
Sulphur (S)	3.8a	8.0b	7.5c	
Zinc (Zn)	8.6a	10.8b	11.2b	200 - 250

*Values in rows followed by a common letter are not different (P > 0.05)

**Soil Contaminant Ceiling Concentration, "Guidelines for Sewerage Systems" National Resource Management Ministerial Council November 2004, Canberra ACT.

Soil health: Improvements in two important aspects of soil health, namely microbial activity (Figures 6.4 and 6.5) and microbial diversity (Table 6.2 and Figure 6.2), have been measured at the Medina trial sites in WA as part of the doctoral studentship associated with the project. Increases in microbial activity have also been measured at the Victorian System trial site (Table 6.4).

In addition to managing losses of soluble nutrients, maintaining effective diverse microbial populations is also likely to be the key to managing many pests and diseases and achieving significant reductions in the use of pesticides (Hoitink 1999).

SOIL HEALTH

- **Compost increases biological activity and diversity.**
- **Active biological populations are responsible for mineralisation and reducing leaching losses.**
- **Biological activity and diversity will potentially reduce the incidence of pests and diseases.**

Strategies for using compost

Achieving maximum benefit from compost use requires a commitment to incorporating the regular use of compost into vegetable growing programs.

Over time, application rates are likely to reduce and or to be restricted to the most responsive crops. However rates and frequencies will inevitably be governed by the production system, prevailing soil and climate, and the need to maintain soil carbon at adequate levels.

At this stage strategies for using compost in vegetable production should include:

- A commitment to its regular use.
- Apply compost at between 20 and 30 m^3/ha and at higher if soil quality is an issue.
- The use of soil and crop analysis to adjust fertiliser programs and manage compost rate.
- Taking time to work with and build a relationship with the compost supplier.
- Working with compost suppliers that provide product information including information on nitrogen content.
- Working with industry suppliers and technical consultants that are knowledgeable in soil management as well as crop production and that demonstrate a commitment to the conservation and development of soil organic matter; and
- A healthy scepticism for statements that promise with great certainty, immediate positive results in all situations.

COMPOST USE STRATEGIES

- **Regular use;**
- **Use of soil and crop analysis;**
- **Adjust fertiliser programs;**
- **Build relationship with reputable supplier;**
- **Use products with available nitrogen (mainly Nitrate N) greater than 100 ma/L.**

Knowledge of soil quality and fertility and its impacts on vegetable crop performance are in the early stages of development however, with common sense and the application of current knowledge, they offer exciting possibilities for:

- Managing and producing high quality crops.
- Significantly reducing inputs of fertiliser, irrigation and potentially pesticide use; and
- Maintaining and improving soil and water quality.

Using compost is first and foremost a tool for improving soil performance and as we learn more about better managing soil organic matter levels, benefits of reduced pesticide and irrigation will become increasingly significant.

Economic considerations

Economic considerations focus on the use of compost alone, however the economics of using clay as a soil amendment are considered briefly.

Returns from using compost depend on improvements to marketable yield and savings in management cost. Management savings universally include reduced fertiliser requirements and with continued compost use there will be irrigation savings and potentially significant pesticide savings.

FINANCIAL BENEFIT
Compost use will improve returns providing:
- **it is used regularly;**
- **quality is appropriate;**
- **fertiliser rates are reduced and managed.**

There will also be benefits associated with increased harvesting efficiency and improved product quality that contribute to better shelf life and increased nutritional value of fresh vegetables.

Because many of these benefits are likely to be site specific and the result of further developments with 'better management practices', we will restrict our economic analysis of compost use to yield improvements typically achieved and fertiliser savings identified in crops grown with compost for the first time.

Using basic Gross Margin Analysis, the increased yield required to cover the cost of a 25 m^3/ha application of compost to selected vegetable crops grown for the domestic Perth market are provided in Table 8.3.

The basic assumptions used for costing compost are:

Applied cost - \$42/ha including:
Application cost - \$7/m^3 and transport cost - \$5/m^3

Fertiliser saving - \$20/m^3 based on research results and cost of urea, superphosphate, potassium sulphate, Agricultural lime and Magnesium sulphate.

Compost analysis - (%); N – 1.5; P – 0.8; K – 0.7; Ca – 2.8 and Mg – 0.30.

Crop returns - Local market prices provided by the Perth Market Authority.

Irrigation - Pesticide and harvest savings; Nil.

Marketable crop yields - Based on mid range typically achieved in our trials, they are within the upper mid range of grower expectations.

Table 8.3. Percentage increase in yield necessary to cover the cost of applying 25 m^3/ha of premium grade compost to selected vegetable crops

Crop	Marketable yield	Unit	Market return \$/unit		% yield increase to cover cost of compost	
			Low	High	Minimum	Maximum
Lettuce	3,800	Crates/ha	5.00	10.00	1.2	2.9
Broccoli	12,000	kg/ha	0.75	1.00	4.6	6.1
Carrots	71,550	kg/ha	0.50	0.75	0.7	1.2

The estimated percentage increases in marketable yield are within the yield improvements typically achieved in our work and underpin the conviction that the regular use of high quality compost will provide a positive return.

The critical issue is that typical improvements to returns based on fertiliser savings and a 4% to 7% improvement in marketable crop for lettuce and broccoli and 2-3% for carrots typically range from $200 to $900/ha and are relatively small, particularly when compared to production costs (Paulin 2004).

With regular compost use, improvements to grower returns will increase and importantly, very significant increases will be achieved from time to time when improved soil performance is able to substantially reduce impacts of management failure and or climatic extremes.

The level of increases will be predicated on growers making appropriate adjustments to fertiliser programs that will increasingly account for their costs of compost application. As indicated from the fertiliser replacement work, two thirds of the compost cost can be covered by reductions in requirements based on the cheapest fertiliser alternatives and given the increasing use of expensive compound fertiliser, these savings have the potential to cover the entire cost of compost.

Irrigation savings have not been considered, largely because of the relative low cost of self supply irrigation that predominates in Western Australia. With irrigation reductions of less than 10% and supply costs in the order of $0.08 to $0.12/Kl (Gartrell 1998) savings are in the order of $240 to $360/ha/yr. These estimates are based on a typical 30,000 Kl/ha irrigation use around Perth in Western Australia and it should be acknowledged that if the costs of irrigation increase to around $0.50/Kl then savings would increase $1,500/ha/yr.

With respect to the use of clay, the cost of application is a major consideration, and while it is not possible to accurately estimate, currently it would be in the order of several thousand dollars per hectare. Least costs application strategies need to be evaluated and although there are sources of material, there is no supply industry in place on which to base costs. From our preliminary findings, savings are at least twice that of compost alone, so that savings would initially be in the order of $500 to $700 increasing up to $3,000/ha/yr if irrigation supply costs rise to $0.50 Kl.

As irrigation supply costs increase, the use of clay is likely to become an increasingly viable option, at least on much of the Swan Coastal Plain in Western Australia.

Developing the vegetable industry compost market

Issues for consideration include:

- cost and value of benefits;
- compost quality and maturation, issues associated with determining compost quality and the 'fitness for purpose' of a given product;
- building linkages between vegetable production and the community through considerations for managing wastes and a range of other mutual benefits.

Compost cost and value of benefits

Benefits of reduced and more efficient use of fertiliser and irrigation can only be achieved when appropriate changes are made to relevant management practices. With sands and very light soils, maximising these benefits and reducing pesticide use in vegetable production is likely to require greater soil carbon levels than can be achieved under current management systems.

Enabling growers to achieve these benefits and particularly fertiliser savings with minimal disruption to tight and often complex cropping schedules will require the information developed to be packaged effectively and most usefully in electronic formats.

These packages should be developed to also assist growers with improving their overall management practices and should incorporate capacity to cost changes and estimate associated changes to returns.

Electronic packages need the capacity to interpret soil analysis results, adjust fertiliser and irrigation programs to match identified best nutrient management practice and ultimately, to assist with making changes to pesticide use that is compatible with integrated programs for managing disease, pests and weeds.

Growers are under increasing pressure to reduce the potential adversely impacts of their management practices on soil and water resources. Participation in building better overall management programs that encompass soil management will invariably result in clearer recognition of the importance of building and managing soil organic matter levels. In the intensively managed horticultural industries, the importance of using compost to manage soil organic matter will become increasingly obvious and will serve to promote these benefits that are not accounted for within normal costing processes.

Current costs and relatively small benefits that frequently arise make the costs of applying compost a major limitation. While it has greater long term value in terms of improving soil carbon levels (Figure 6.1) and associated soil performance, compost is not competitive with raw manures and other organic products that are currently available.

In Western Australia, raw poultry manure costs less than half the applied cost per cubic metre of compost. Poultry manure also contains over twice the nitrogen content (3.5% compared to < 1.5%) and that nitrogen is much more readily available. While that nitrogen will also leach more readily its greater availability is what is important within conventional management programs and with the unit cost, explains grower reluctance to consider the use of compost.

Serious consideration therefore needs to be given to making the use of compost more economically attractive to growers, at least in the short term so that they have the opportunity to use it and appreciate the greater range of benefits that will accrue over time. This could be achieved by providing rebates on compost use that could be funded from landfill levies. The supply of compost that consistently provides plant available nitrogen at crop establishment will also increase the value of compost to the vegetable industry.

Finally many of the benefits associated with improved soil quality and performance are not realised in any financial sense and therefore at least in the short term cannot be factored into finance based decision processes. This is further reason for considering processes that encourage the use of compost over an extended period of time to enable these benefits to develop and reflect in at least a level of financial saving.

Compost quality and maturation

Compost maturity is the factor that determines compost quality in terms of its best use and it reflects the degree to which the second mesophyllic composting stage (Figure 8.1) has progressed.

There are large volumes of research into compost maturity and a consistent conclusion is that it cannot be defined by a single measurement. Recent work to develop a compost maturity index by a group lead by Dr Marc Buchanan (Cotton 2002) for the Californian Compost Quality Council (CCQC) has considerable promise.

The CCQC compost maturity index involves three tests that include the Carbon: Nitrogen ratio, one test for potential plant toxicity (germination, Ammonium nitrogen level) and one for compost stability (rate of oxygen uptake, carbon dioxide production, Reheat test). Based on critical values from each of the tests, the compost is given a maturity score/rating between 1 (immature) and 5 (highly mature).

This index has been validated using an extensive range of commercial composts in commercial vegetable trials (Buchanan 2002). This work indicated that composts with a rating of 2 to 3 are most likely to improve crop performance through its ability to supply crop available nitrogen. The potential importance of this maturity rating is to provide a quantitative measure of maturity and enable the production of more consistently performing compost.

The suite of analysis conducted for the composts used in this project did not include a test for stability. However nitrogen analysis values that are within the established limits for total inorganic nitrogen (>100 mg/L) and the dominance of Nitrate nitrogen (Nitrate to Ammonium nitrogen ratio >0.14) indicate a compost is likely to stimulate mineralisation, and perform well in vegetable production providing soil organic nitrogen reserves are adequate..

Compost with adequate plant available nitrogen that is predominantly in the Nitrate form is likely to perform well in vegetable production.

Investigation the Californian Compost Maturity Index under Australian conditions and with local composts would provide opportunity to further test our findings with respect to compost nitrogen analysis and to confirm that maturity levels are useful in quantifying the potential for achieving other benefits from compost use.

Composts made with woody wastes as a significant component of the feedstock present additional considerations. Decomposition of woody lignified materials, particularly during the initial composting phase is limited because the bacteria responsible can only act on the exposed surface carbon. Unless time is not a concern, the production of compost from woody feedstock needs to involve screening to remove larger fractions that potentially contain undecomposed carbon.

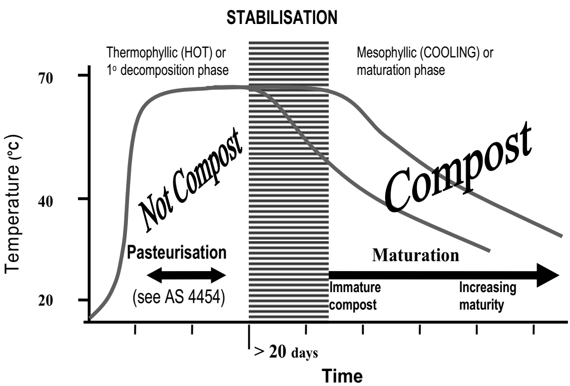


Figure 8.1. Diagrammatic depiction of the vessel composting process.

With conventional windrow composting the normal expectation is to produce compost for use in vegetable production within 10 to 14 weeks. Our work backed up by findings of a recent tour of compost production in California (Paulin 2002) indicate that to achieve this using woody feedstock's, screen sizes in the order of 10 mm are required

Role of standards and regulation

The Australian Standards for Compost, Soil Conditioners and Mulches AS-4454, set out a range of minimum test values for compost and related products. They also define procedures and protocols for their measurement.

The standards also define minimum requirements for protecting community health and the quality of our soil and water resources. This is achieved through reference to the Standards for the application of 'Biosolids' to land and to relevant Public Health Standards provided by the Health Act.

All organic wastes posse significant risks to the community, agriculture and natural resources, and composting together with compliance with the Australian Standard AS 4454 manages these risks (Millar 2002).

Manures, sludges and food waste all contain diseases and pests, often high levels of heavy metals, as well as significant levels of nutrient and particularly nitrogen that have the potential to contaminate ground water.

The present uncontrolled distribution of 'raw' mulched plant material contributes to the spread of diseases, pests and weeds, and is totally unacceptable to commercial agriculture and should be unacceptable to the community. This practice also possesses potential biosecurity concerns, particularly when time delays between a biosecurity incursion and its detection allow its significant spread, as was the recent case in California with Sudden Oak decline.

In Californian compost producers are licensed and as part of license conditions, they are required to demonstrate compliance with minimum standards that cover a similar range of issues to those covered within AS 4454. This approach will provide compost users and particularly growers with much greater assurances that a compost product has at least been adequately pasteurised.

The application of these minimum standards through a process that licenses all organic waste industry participants would address the broad range of crop and human health as well as environmental and biosecurity concerns that are associated with organic wastes. It would also address compost's current lack of competitiveness with raw manures and allow all organic products to compete on the basis of performances, rather than just on cost!

Building linkages between agriculture and the community

The benefits from the soil application of organic wastes to soil and water resources, to agricultural productivity, and to the environment are being increasingly better understood.

This is illustrated by a recent resolution by the Soil Science Society of American advocating global enhancement of soil organic matter. The resolution put up for international adoption, stated:

> "**We resolve that organic matter is a resource that must be restored and increased globally to reduce the net rate of increase in greenhouse gases, to increase plant productivity and improve environmental quality**".
> *Global climate change, food security and environmental quality are interrelated*

issues of importance to all Nations and our Planet, and these can be favourably and simultaneously addressed by global enhancement of soil organic matter.

The significance of managing soils and particularly the potential to use composted organic waste is also being addressed by the European Union development of a comprehensive policy to protect soil. EU-25, the Thematic Soil Strategy for ‘Organic matter and compost quality in the future’, brings together the findings of five interdisciplinary working groups. In summarising their work it emphasises the inherent link between soil quality and the use of composted exogenous organic matter.

This project has clearly identified the linkage between soil carbon and the recycling of organic wastes as compost, providing minimum standards for land application are met.

Recognition of the strategic importance of agricultural land in the planning process resulted in the recent establishment of a Statement of Planning Policy for Productive Agricultural Land (SPP 2.5), in Western Australia. However despite this initiative, the planning process continues to support the paradigm that the needs of agriculture are subservient to the requirements for urban growth. This situation and the failure to address it is common to urban development areas throughout Australia and most of the Western World.

Implementing a planning process that addresses the strategic importance of agriculture is likely to be more readily achieved when all of the potentially linkages with sustainable urban development are considered and are fully appreciated. These linkages relate to:

- Agricultures contribution to zero waste objectives through its potential to beneficially reuse the major organic component of the waste stream.
- Recognition that vegetable production and other irrigated horticultural activities are major potential users of reclaimed water via groundwater recharging. To justify the capital investment for this to occur, permanent agricultural zones or precincts will need to be established.
- Agriculture’s reuse of organic waste will reduce the negative impacts of these industries on soil and water quality. This outcome will be of greatest immediate importance if the use of reclaimed / recycled water in horticulture, either through direct supply or groundwater recharging, results in the establishment of precincts for long term intensive horticultural production.
- The production of fresh food with maximum nutritional value and therefore maximum potential to reduce health costs requires transport and storage to be minimised and fresh food production to be retained close to urban centres .
- Contribution to employment, tourism and agri-business opportunity and to the diversity of social and community values associated with rural landscapes in the peri urban environment.

Greater appreciation of these linkages and especially the potential for agriculture to utilise reclaimed water and hence free up water for other uses, has the potential to facilitate changes to the current dominance of urban needs in the planning process.

An added benefit from strategic planning process that better accommodates the needs of agriculture and particularly long term food production will be additional protection for natural ecosystems as well as environmental and social values that are associated with rural landscapes. This will come about through the maintaining viable rural economies that will in turn be underpinned by viable intensive horticultural industries and particularly vegetable production.

Conclusions

Fertiliser savings, moderate to small increases in marketable yield, irrigation savings along with other potential benefits to production efficiency and improved environmental outcomes combine to make compelling arguments for the use of compost to contribute to a more productive vegetable industry.

Consistently achieving increased returns from using compost, at least in the short term, will require adjustments to fertiliser applications. The need to adjust fertiliser programs, to store and spread compost, and the perceived risks associated with the capital outlay ($800 to $1,000/ha)required to apply compost at the commencement of the crop cycle, explains the relatively slow adoption of compost use and emphasises the need for:

- The provision of services that better enable growers to adapt their practices and capitalise on the benefits associated with compost use, including reduction in fertiliser and potentially irrigation.
- The ability to quantify compost maturity and therefore to ensure that its performance is reliably maximised.
- Keeping compost cost as low as possible by ensuring that costs associated with the collection and management of organic wastes are born by the waste producer rather that the user of the composted product.
- Encouraging the production of compost that is appropriate for use in vegetable production and the adoption of independently audited quality management processes by the compost industry; and
- The potential environmental benefits from compost use, such as more efficient use of irrigation and fertiliser, to translate into additional returns. Policy and regulation that reward growers for managing soil and water resources will inevitably favour shifts in management practice that favour the use of compost.

In addition to direct benefits to productivity and grower returns, our work demonstrates the critical importance of a greater:

- Focus on the importance of soil organic matter in the development of more sustainable, lower input, vegetable production systems; and
- Awareness that conserving and building soil organic matter effectively ‘bullet proofs’ soils, making them more resilient and productive and contributing to the development of ‘best production practices that incorporate a significant ‘EMS – Environmental management system’ focus.

This approach will minimise potential negative management impacts on soil and water quality while minimising costs of fertiliser, irrigation and ultimately pesticide costs.

Without incentives, the adoption of these approaches based on the use of compost and adjustments to management, even when fully developed, will be slow because the benefits tend to be long term and accumulative rather than short term and immediate. The development and adoption of ‘soil carbon based’ practices will be encouraged by:

- Information packages (Electronic and written) that assist growers to change management with minimal disruptions. They also need to be constructed to assist with quality assurance and environmental management.

- Market demands for environmental management systems and greater food safety.
- Increasing costs of water.
- Increasing license requirements for the adoption of more efficient irrigation and fertiliser management practices; and
- Planning processes that better recognise the strategic importance of horticulture in reusing organic wastes as well as reclaimed water, and complimenting urban community needs through providing fresh food, employment, agri-tourism / business opportunities, and contributing to the protection of both community and environmental values.

SECTION 9 – RECOMMENDATIONS

Our work indicates that in most situations, the financial benefits to vegetable grower from using compost are positive but usually small. These investigations have identified that:

- Compost needs to be used regularly;
- Available nitrogen analysis, dominated by Nitrate nitrogen needs to be adequate (>100 mg/L);
- Variable compost quality will frequently reduce benefits and can result in reduced returns; and
- In many situations, increased returns will only be achieved if savings associated with reductions in fertiliser use can be realised.

It is also important to appreciate that making these changes is not a simple matter for many growers!

Develop compost use as integral component of vegetable management program:

- **Identify and develop management practices that maximise soil organic matter**
- **Develop management practices to facilitate grower use of compost with minimal disruption to management**
- **Confirm compost analysis values that identifies best maturity for vegetable production (Maturity index - Available nitrogen >100 mg/L and mainly Nitrate N)**

Finally, mutual benefits to the wider community in general that arise from vegetable industry and other horticultural reuse of organics, need to be included. These benefits include:

- Improved productivity and potentially, the quality of fresh food;
- Environmental benefits that will flow from building soil carbon and related contributions to the development of biological activity, soil health and soil fertility;
- Contribution to achieving 'Zero Waste' objective.

Key issues to be addressed

Factors limiting farmer use of compost

The use of compost, particularly in vegetable production is limited by its cost relative to other organic inputs as well as by policy settings that do not reflect a priority for recycling organic materials back to the land and land use planning process that fails to create permeance within productive agricultural areas that would encourage investment in building soil quality.

A contributing factor to the slow pace of progress with increasing compost use by vegetable growers could also be an inadequate understanding of farming enterprises, what motivates farmers to change practice (in this case to adopt compost products) and what are the barriers to changing existing and developing alternate management practices. 'Practice change' research seeks to address this gap in knowledge by understanding the farming context, identifying needs and designing a more effective management systems and better targeted extension strategy. The modest progress made in developing markets to date through field trials, promotional campaigns and marketing studies could reflect that this background research has not been conducted.

Compost quality

Consistency of compost performance is largely determined by composting process management and reflects its level of maturity. Maturity is a function of the second stage of the composting process (Figure 8.1) and is not readily quantified by any single measurement. Some progress in quantifying maturity has been made by the Californian Integrated Waste Management Board who sponsored the development of a Compost Maturity Index by Dr Mark Buchanan and a panel of noted commercial compost producers in the United States. However analysing the nitrogen content of compost, in line with recommendations for levels and nature of available nitrogen, provide a strong indication of its suitability for vegetable production and may be particularly useful for organic growers.

Crop production systems development

The use of compost needs to be viewed and developed as part of the vegetable production system and its widespread use will be more likely when overall system improvement can be achieved. Growing emphasis on developing environmental management systems (EMS) will be facilitated by including the use of composts. Along with a strong focus on soil performance, this will allow the delivery of environmental and socially beneficial changes to management along with the maintenance of critically important productivity and financial security.

Investigating factors and mechanisms that contribute to soil biology and its management under commercial production also need to be included if we are to produce compost that performs reliably and that consistently:

- Stimulates mineralisation and the supply of nitrogen and other nutrients.
- Manages pests, diseases and possibly weeds.

Opportunity to share and discuss current knowledge and experience with building soil carbon based production needs to be facilitated. The process should include an annual two day working conference that focus on developing sustainable soil based production systems for vegetables and other key horticultural industries. They could be held on a rotational basis around Australia at Universities or other similar low cost venues.

Researchers and practitioners involved in soil health, fertility and management that may not have involvement with the use of compost or soil organic matter investigations such as crop rotation, integrated pest management and permanent bed production for vegetables, and inter row sward management/cover cropping in perennial crops, need to be included.

A National workshop for researchers has been held by Compost Australia and needs support for it to become an annual national event.

Information packaging and marketing tool

Generic tools need to be developed that assist growers and consultants with making changes that maximise potential benefits from compost use, such as adjustment to fertiliser programs and other management practices, and that contribute to developing overall environmental management systems. This project has developed information required to develop these tools, however this information needs to be incorporated into user friendly computer based packages.

Short term investigations (< 3 yr)

Investigate factors that limit farmer use of compost

Maximising the benefits of compost use in vegetable production will potentially require changes to production systems and consequently unique adjustments to be made by individual growers. An investigation is needed into the most effective means of facilitating this change. To enable the best extension and research programs to be developed (to facilitate change), social researchers and extension practitioners should be engaged to investigate the needs of farmers and identify the barriers and limits to management change. The aim of this project would be to develop a 'compost adoption strategy' to address the differing needs and drivers for growers in various regions and situations that include key messages and effective delivery mechanisms.

Potentially this process could be developed nationally with the aim of facilitating the development of improved production systems that embrace the 'EMS - Environmental Management System' concept for a wide range of horticultural and agricultural industries. By focussing on managing soils for greater productivity, the role of compost would be dependant on the situation and its associated economic considerations.

In subsequent years a program for implementing the compost adoption strategy should be rolled out, see Long term Production system Development.

Quality/maturity studies

To build on current knowledge and utilising the Californian Compost Maturity Index, undertake:

- Laboratory studies to identify factors in compost production (feedstock/C:N ratio, logged temperature, moisture and turning frequency) and compost analyte values that contribute to crop improvement. This will include refining knowledge on key factors that influence compost performance and determining methodologies.
- Coordinated National program to evaluate the findings using commercial composts applied to vegetable as well as other horticultural crops.

Management tools

Directions for refining and further developing management tools and information packages will result from identifying factors that limit grower use of compost and associated development of improved management systems. In the immediate term it is important to identify and make best use of information that is currently available.

Long term investigations (> 3 yr)

Production system development

The identification of factors that limit compost use in agriculture will provide much of the detail for the development of more productive, as well as, environmentally and socially responsive farming systems. Broadly, achieving significant compost utilisation within vegetable production will be based on grower acceptance of:

- Its benefits;
- How it can be used to address issues and how to maximise its benefits; and
- Its financial benefit.

The focus needs to be on working with growers to identify aspects of their farm and its management that limit crop performance and to provide support that enables solutions to be developed, evaluated and implemented.

A national project could be developed from the proposed needs analysis and would become a key focus for the proposed National Research and Development workshops. The project needs to:

- Have strong grower ownership, a function of the process.
- Work with individual or groups of growers at the 'whole farm' development level.
- Work through grower support groups and consultants.
- Provide support groups of experts – agronomists, soil management as well as pest and disease specialists, etc. that will assist grower decision making.
- Measure and evaluate outcomes of process including the evaluation of options; and
- Test and further develop packaged information and programs.

From the start, the project will also engage with and assist compost producers to better understand grower needs and assist them in the development of appropriate products to best meet those needs.

Rather than assisting with the DIRECT MARKETING OF COMPOST, the focus of this project will be to develop better vegetable production systems based on improving soil performance that will in most situations, result in an increased use of compost.

Integrating the promotion of the potential social and environmental benefits of agricultural compost use, such as community waste management and resource protection, will contribute to developing more appropriate policy and planning processes that will inturn underpin the development of a significant compost market within vegetable production.

Biological initiatives

There are three elements of University based work at PhD or masters level that could potentially be funded in partnership with existing university grant systems.

They would specifically develop the science relating to soil biological attributes that contribute to the production of compost and that:

- Maximise soil carbon accumulation and building related soil properties that will make them productive under vegetable production – 'Bullet proofing these soils';
- Promote effective nitrogen/nutrient cycling; and
- Promote disease and pest suppression.

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