The Cost-Benefits of Applying Biosolid Composts For Vegetable, Fruit and Maize/Sweetcorn Production Systems in New Zealand

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Executive Summary

The issues

New Zealand waste management coordinators face many problems as waste levels being produced increase. Many of the country's landfills are nearing capacity. There is increasing public pressure to find alternative methods to landfill waste disposal. New Zealand's waste stream comprises approximately 50% biodegradable waste, and this waste has the biggest potential for alternative disposal.

Composting and land application of biosolids are becoming increasingly popular ways to use this organic waste, and to decrease the amount of waste being diverted into landfills. Trials overseas, in particular the USA, have shown that the land application of biosolids/composts can improve many soil properties including: soil water-holding capacity, bulk density, cation-exchange capacity, organic matter, microbial population size, soil texture and soil structure.

Yield improvement data are not as comprehensive as soil quality data, but some yield improvements have been claimed where composts have been included in the growing system. However, many of the trials that stated yield benefits used application rates far exceeding the Living Earth Limited's Wellington biosolids compost resource consent limit of 12.5 tonnes/hectare/year.

There are many benefits that can be achieved by using composts. Compost use has been established in the home gardening market, but its use in horticulture and agriculture has been limited. Our survey revealed perception among some growers and food processors of heavy metal contamination from biosolids compost. Although we did not find any documented cases of heavy metal contamination in New Zealand, the perception deters some growers from using biosolids, for fear that their crops may not be accepted by the processor.

While the costs-benefits of applying fertilizers and weed, pest and disease management for horticultural systems are well known and understood by producers. Information on the costs and benefits under New Zealand conditions of soil conditioning through applying composts are not, however, readily available. There are plentiful data on the biophysical benefits (improvements to soil structure, water holding capacity, nutrient supply, earthworm populations, etc.) of applying composts in horticulture but data have not been compiled on the financial benefits.

Through Living Earth Limited, the Ministry for the Environment commissioned Landcare Research and Massey University to review the international literature, interview key compost users in the horticultural community, assemble the information on benefits of composts and calculate gross margins (total revenue less total costs) using New Zealand data.

Conclusions and recommendations

Based on a review of international literature, on interviews with key compost users in the horticultural community, and on limited New Zealand data using gross margins (total revenue less total costs), this study indicates an increase in gross margin with the application of compost when compared with conventional fertiliser use. The main cause of this was the large difference in the purchase price of the composts compared with the various conventional fertilisers. The sensitivity tables completed also showed the gross margins for each of the compost-amended crops were sensitive to both yield and spreading cost, when compared with crops grown with conventional fertiliser use. However, this analysis has not considered the potential for combined applications or long-term benefits of compost use such as benefits from improved soil structure.

Despite these findings, it is difficult to recommend compost use on its financial merits alone. Often farmers will not adopt a new technology until it proves to be financially worthwhile. Yield data for compost-amended crops vary considerably, and accurate assumptions are difficult to make. Many benefits for sustainable cropping that occur when composts are added to growing systems do not have a specific monetary value, and therefore cannot be easily included in financial analyses.

In addition to providing an initial indication of the cost-benefits of compost use, areas for further research and/or trial work are identified. Further long-term research into the use of compost in crop production systems needs to be carried out in New Zealand, under a variety of soil, climate and production conditions.

1. Introduction

In the last 50 years as the worlds' population has multiplied, environmental problems have become an issue. In the 21st century the waste this population generates and its disposal have become a key focus. Furthermore, the problem is exacerbated by the increasingly stringent regulations regarding waste disposal of various regulatory bodies. In New Zealand, as landfills are nearing capacity, pressure is mounting on land management groups, such as Regional and District Councils, to find alternative options for waste disposal.

A significant proportion (up to 50%) of New Zealand's waste stream is made up of biowaste. **Biowaste** is any organic waste capable of decomposing either through aerobic or anaerobic processes. It includes food waste, garden waste, animal manure, woodchips and biosolids (sewage sludge) (Living Earth 2003; Roe 2003).

Composting is the biological decomposition of organic materials, substances or objects under controlled circumstances to a condition sufficiently stable for nuisance-free storage and safe use in land applications. During the composting process, various microorganisms, including bacteria and fungi, break down organic material into simpler substances. Composting has the potential to manage all the organic material in the waste stream that cannot otherwise be recycled. Some examples of organic material that can be composted include food scraps, leaves and yard wastes, agricultural crop residues, paper products, sewage sludge and wood. Agricultural wastes have been composted since the beginning of agricultural practices. Large-scale composting of other organic wastes, including municipal sewage sludge, has been a component of some municipal waste management programmes.

Biosolids

Biosolids are the nutrient-rich organic materials resulting from the treatment of sewage sludge often combined with other organic materials such as green and woody wastes, and act much like slow-release organic fertilisers. This treated and processed sewage sludge can be safely and sustainably recycled and applied as fertiliser to improve and maintain productive soils and stimulate plant growth. New Zealand produces approximately 77 000 t of dry sludge solids per year (Wang & Magesan 2003). More than 70% of this is generated at the three main population centres – Auckland, Wellington and Christchurch. These biosolids have traditionally been removed to local landfills but as space in these landfills becomes limited, alternative methods of disposal need to be considered. Until recently, biosolids have not been applied in appreciable amounts to agricultural land in New Zealand. However a recent government decision banning the discharge of sewage, treated or otherwise (New Zealand Marine Safety Authority; http://www.msa.govt.nz/Publications/publication/dumping.pdf), into the ocean and restricting its incineration (New Zealand Ministry for the Environment http://www.mfe.govt.nz/publications/air/air-quality-standards-nov03/index.html), means there will be a ready supply of biosolids and compost for land managers to use. Farmers and growers will need to change the ways in which they manage their operations for this to occur.

Internationally, land application of biosolids is becoming an increasingly popular way to use this organic resource, with many government bodies developing guidelines for the land application and use of biosolids. Examples in New Zealand include the New Zealand Water & Wastes Association (NZWWA) Biosolids Guidelines (NZWWA, 2003), for biosolids reuse, sponsored by the Sustainable Management Fund, and specific rules relating to biosolids in Regional Plans around New Zealand. The Biosolids Guidelines are designed to provide a framework for biosolids management in New Zealand that enables their land application in a way that maximises the benefits and minimises the risk of adverse effects on human health, the environment and the economy. From the supply side, the New Zealand Waste Strategy 2002 confirms this by stating:

> "By 2007 more than 95% of sewage sludge currently disposed of to landfill will be composted, beneficially used or appropriately treated to minimise the production of methane and leachate" (MfE, 2002).

In New Zealand, the composting of biosolids has increased in the last 5 years with the development of a number of composting facilities around the country, the largest being a $17.5 million plant sited near Wellington (Naylor et al. 2000). At this plant, biosolids from the dewatering plant at Careys Gully are composted with green waste such as shredded yard trimmings and garden waste and sawdust.

To ensure pathogens and weed seeds are killed, the composting processes involve a number of steps, which should be followed (Ozores-Hampton & Peach 2002), including procedures to ensure the compost complies with the requirements of USEPA Part 503 rule for temperature and time. This ensures the product is pathogen free, stable, and not attractive to vectors such as rodents and flies. Product monitoring is required to check levels of Salmonella and faecal coliform remain within/below levels set by the Ministry of Health (Naylor et al. 2000). Particular attention is paid to the levels of pathogens in biosolids compost, as public perceptions about the presence of pathogens can lead to resistance to compost use. The operators of some food production systems have resisted the use of biosolids because of their concerns about the public's perception of pathogen levels. The application of biosolids to horticultural land is common in places such as the USA and UK, provided the product and treatment process complies with regulations. By adhering to the guidelines set by the NZWWA, the compost industry minimises the risks and hopes to maximise compost use.

Elevated concentrations of a number of heavy metals such as arsenic, cadmium, chromium, copper, mercury, nickel, lead or zinc (McLaren & Cameron 1996) in biosolids, particularly where industrial waste contributes to the sewage system, further increase negative perceptions about using biosolids (Ozores-Hampton & Peach 2002). Use of phosphatic fertilisers especially in the dairy industry, pesticides and fungicides in agriculture, and by products from metal working processes, painting, dyeing, and wood preserving are the main contributors of heavy metals such as cadmium, copper, zinc, arsenic, nickel to the sludge in the industrialised areas of New Zealand. Limits have been placed on the allowable concentration of these heavy metals in biosolid compost. Land application of biosolids is an effective method of disposal but there is concern about their deleterious effect on soil quality as they contain potentially toxic heavy metal elements that can accumulate in the soils.

To avoid contamination of the soil where biosolid compost is applied, application rates for Living Earth biosolids compost have been capped by resource consent, with a maximum allowable rate of 12.5 tonnes per hectare per year for broad-acre use in New Zealand (Living Earth 1997). The NZWWA Biosolids Guidelines propose an application rate of compost to supply 200 kg N/ha/yr, provided the contaminants levels are low. Therefore, in most cases of biosolids application @12.5 tonnes per hectare N is likely to be limiting, unless contaminants levels are very low. Note that for compost in general (i.e. non-biosolids) there are no controls on application rates although discussions are underway with Standards NZ about developing NZ standards for compost that may include application guidance.

Despite some of the perceived drawbacks of biosolid compost, its use has proved beneficial in many cases (C.M.W.S.P.C.H.C 1996; Maynard 1995; Ozores-Hampton et al 1994; Ozores-Hampton & Peach 2002; Wang & Magesan 2003). The benefits of an application of any compost to soils include improvements in: bulk density; cation exchange capacity; soil water holding capacity; organic matter content; microbial population size; soil texture and structure (Ozores-Hampton et al 1998; Ozores-Hampton & Peach 2002; Roe 1998; Rosen et al 1993). These improvements result in soils being easier and more friable to cultivate than when conventional fertilisers are used. Soils that have had compost amendments allow improved root penetration and growth, and improved plant performance can thus be expected compared with intensively cropped soils that have not had compost added.

These benefits are particularly important for intensive growing systems such as market gardening, or for intensive arable cropping. It is often the practice to grow crops continuously and allow little time between crops for the soil structure to recover or for soil organic matter levels to improve. This soil degradation can lead to structural breakdown and often results in poor crop yields, despite the addition of suitable levels of fertiliser (Shepherd et al. 2001). The addition of compost is a quick, efficient and long-term way of restoring the soil structure, and in turn improving crop yields (McLaren & Cameron 1996). It is these improved soil characteristics that encourage growers to switch from their conventional fertiliser practises to using compost products. Because most composts are low-analysis fertilisers with N and P levels near 1% (Sikora 1998), nutrient amounts supplied by compost are lower than those supplied by conventional fertilisers. Although conventional fertilisers supply higher amounts of nitrogen immediately compared with composts (Rosen et al. 1993), composts are as effective as conventional fertilisers because of their long-term nutrient supplying characteristics (Edmeades 1999; Roe 2003). To ameliorate soil physical conditions it is important to build up organic matter in the soil and improve its structural stability (Ball et al. 1997). If appropriate management strategies are developed, biosolids and composts could become potentially valuable sources in agricultural systems. Biosolids can replenish the supply of humus and improve soil biological and physical properties.

Despite the apparent advantages of using compost, it seems surprising that many growers still use conventional fertilisers. Perhaps they feel the costs of using compost outweigh the benefits that can be derived from it or they are unaware of the benefits that can be derived through compost use.

Use of composts for horticultural production has the dual benefits of recycling wastes and improving soil physical, chemical and biological conditions. It counters the rundown of soil organic matter and associated effects on soil degradation, commonly experienced in intensively cultivated agricultural systems. Repeated compost additions over several years may also sequester carbon in the soil thus contributing to the mitigation of greenhouse gas emissions. Well-structured soil requires less cultivation to develop seedbeds than poorly structured soil. Compost applications may also reduce some pest and disease problems. Thus, in addition to the direct benefits of biosolids application to crop production and quality, there are indirect environmental and farm management benefits that need to be accounted for.

This study:

- reviews the national and international literature on the direct and indirect benefits of using composts in agricultural soils
- interviews key compost users in the horticultural community
- calculates the cost-benefits of adding compost for horticultural systems using gross margins (total revenue less total costs)
- makes recommendations based on existing limited New Zealand data
- identifies further research and/or trial work to contribute to the development of future compost use in New Zealand.

Note: A number of composted organic materials such as Farm Yard Manure (FYM), Biosolids, Municipal Sewerage Waste (MSW), Greenwaste etc. are in use. The generic term **Compost** is used hereafter for those composting products that are used or sold for use as a soil amendment, artificial topsoil or growing medium or for some other application to land in accordance with the country specific regulations.

2. Benefits of Compost Use: International Literature

The need to add compost to soil stems from the close relationship of a soil's natural fertility and its organic matter content. Organic matter is vital to a soil's productivity and sustainability. Humic acids, one of the most active fractions of organic matter improve the absorption of nutrients by plants and soil microorganisms; have a positive effect on the dynamics of nitrogen (N), phosphorus (P) and sulphur (S) in soil; stimulate plant respiration and the photosynthesis process; and favour the formation of soil aggregates. Soil scientists and plant physiologists state that plant growth and yield are largely determined by mineral nutrition, water and air supply to roots and environmental conditions such as light and temperature. However, a number of studies suggest soil organic matter (SOM) also affects plant growth. Correlations between organic matter content of soils and plant yields are reported in the literature (e.g., Scharpf 1967; Agboola 1978; Rebufetti & Lubunora 1982; Olsen 1986). SOM may affect soil fertility indirectly through following mechanisms:

- Supply of mineral nutrients N, P, S and micronutrients to roots
- Improved soil structure, thereby improving water-air relationships in the rhizosphere
- Increased microbial population including beneficial microorganisms
- Increased cation exchange capacity (CEC) and the pH buffering capacity of the soil
- Supply of defined biochemical compounds to plant roots such as acetamide and nucleic acid
- Supply of humic substances that serve as carriers of micronutrients and growth factors

The multi-functions of SOM in agricultural sustainability are well documented (Stevenson1994). Man has realised for thousands of years that dark-coloured soils are more productive than light-coloured soils and that productivity is closely associated with decomposing plant and animal residues. Best yields were obtained in the long-term field experiments at Rothamsted (UK) following the introduction of high-yielding wheat and barley cultivars from plots with higher SOM levels resulting from farm yard manure and N fertiliser application (Johnston 1993). In recent years, the additional role of SOM as a major source and sink of greenhouse gases in the atmosphere is receiving increasing attention.

In the USA, many trials have been performed using MSW and other composts as a soil amendment (Hormann et al 1994; Ozores-Hampton et al 1994; Schreeg & Jarrett 1996; Zhang et al 2000). Few of these authors reported directly on the yield improvements achieved by their research activities, but focussed rather on improvements in soil quality.

Limited data have been collected about yield increases derived from the application of compost to range of crops. In the most spectacular of these, Logsdon (1993), reported yield increases of 35% for both barley and wheat in Washington State, when a form of sewage sludge was ploughed into the field at a rate of 4.5 dry t/ha/year prior to planting.

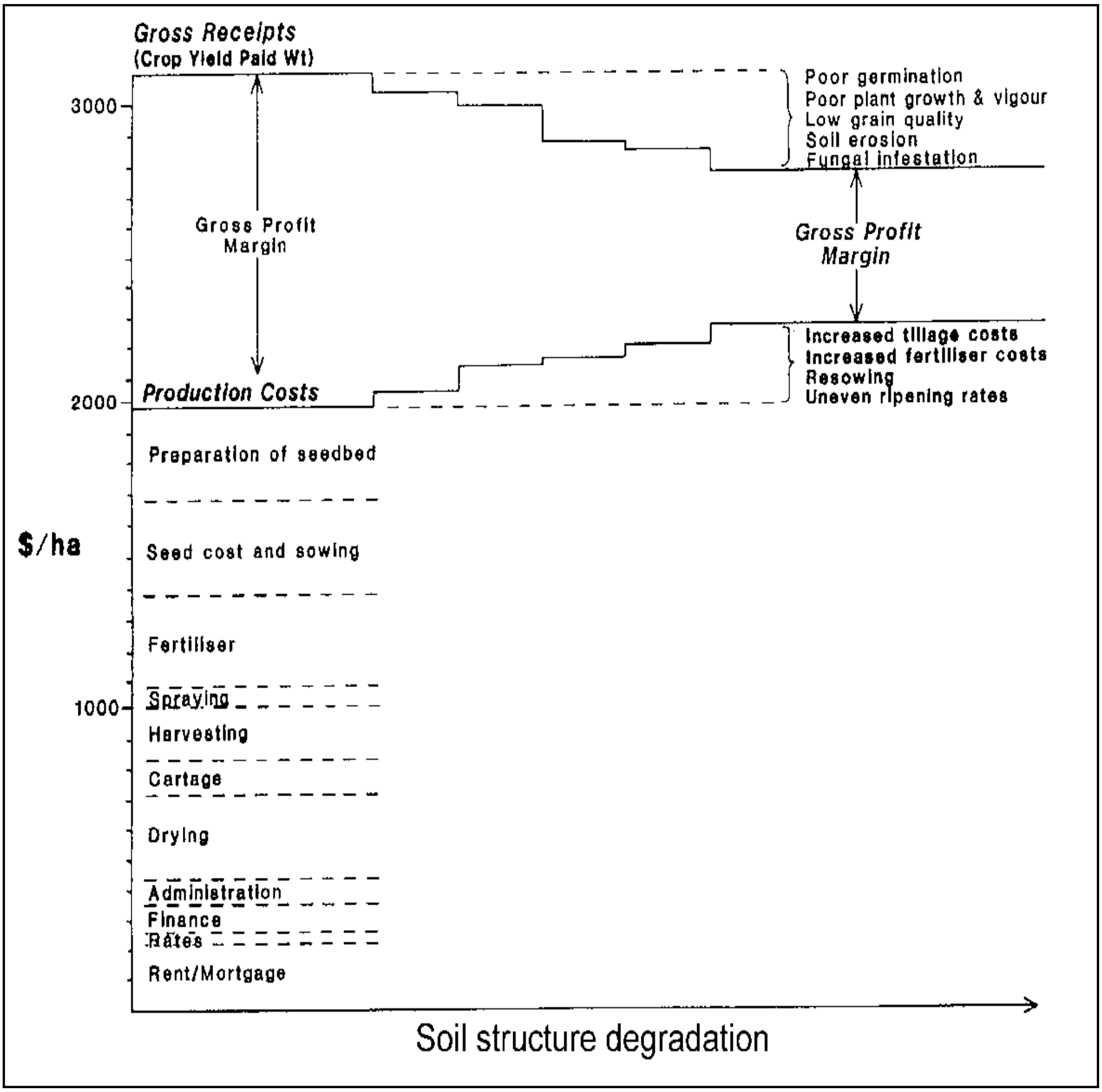
Tomatoes have also shown to be very yield responsive to additions of compost (MSW). On a fine sandy loam in Connecticut, average fruit yields were significantly greater for those plots amended with approximately 50 t/ha of compost (MSW) compared with the controls (no compost added). Over a 3-year period, the average yield from the compost-amended plots was from 4.89 to 8.85 kg/plant compared with 3.54 to 7.67 kg/plant in the control plots. The average for these ranges resulted in an increase of tomatoes from 5.6 kg/plant to 6.9 kg/plant, or a yield improvement of 18%. This increase in yield was the result of both an increase in the number of fruit per plant and in the individual weight of each fruit (Maynard 1995).

Warman (1998) reported that when compost was amended to a plot trial, marketable carrot yield, as a percentage of total yield, was increased 9%, from 67% to 76%, compared with conventional fertilisers. This trial was one of the few that were carried out over a number of years. Unfortunately, the trial results were mixed, with improvements in some crops (carrots and tomatoes) in some years, and no improvement in other crops (broccoli and onions) in other years. Warman suggested crops with a lower N requirement, such as tomatoes, benefit more from compost addition than crops with a higher N requirement (broccoli).

Smith et al. (1992) also reported yield increases in pepper and cucumber crops where compost was added at a rate of 60 t/ha to a sandy soil, although the amount of this yield increase was not quantified. Hornick and Parr (1987) described the application of sludge composts to sand gravel soils used for corn and bean production. Once again, although these authors reported on improved yields in both crops they failed to quantify both the yield improvement attained and the rates of sludge used. From a practical perspective, this research is of little use.

3. Benefits of Compost Use: New Zealand Literature

The maintenance and improvement of organic matters levels in soil is generally considered an important aim for sustainable agricultural production systems. As described in the previous section, because of its binding and cementing action soil organic matter has a particularly important role in relation to soil structural stability. The loss of soil structure results in poor crop growth and yield. Yield declines reduce profitability and reduction in profitability reduces the value of the asset (Scrimgeour & Shepherd 1998). Poorly structured soils produce a lower return due to lower yields and revenues in combination with higher input costs. The economic impacts become severe as the loss of organic matter continues and soil structure declines (see diagram below; Shepherd et al. 2000).



Despite the well-described advantages of soil organic matter and an improved soil structure, few commercial growers actually apply any form of organic matter to their land.

Traditional tillage techniques are known to damage soil structure, particularly when soils are wet, as well as reduce the amount of organic matter in the soil through oxidation (McLaren & Cameron 1996; Haynes & Tregurtha 1999; Saggar et al. 2001; Shepherd et al. 2000; 2001). To conserve soil structure and soil organic levels many growers practise minimum tillage that avoids unnecessary ploughing and disking of soils before planting.

Growers also use a variety of crops in the rotation to minimise the effects of cropping on soil productivity. Crop rotation may include growing a restorative grass or grass/clover pasture within the cropping cycle. A number of New Zealand studies by Haynes and co-workers (Haynes 1999; Haynes & Francis 1990; Haynes & Swift 1990; Haynes & Beare 1997; Haynes & Tregurtha 1999; Haynes et al. 1991; Francis et al. 1999), and Shepherd and co-workers (Shepherd 1992; Sparling et al. 1992; Shepherd et al. 2001) show SOM levels can be increased by alternating periods of cropping with periods in which soil is returned to pasture. This helps replace organic matter lost under cropping and restore structural damage that may have occurred. Return of organic matter to soil is usually higher in pastures than arable land (Saggar et al. 2001). This period of pasture helps restore the organic matter level of the soil, and allows time for the soil structure to re-establish. The disadvantage is that it takes land out of the cropping cycle for a period of time.

In addition to the practices described above, some growers practise green manuring (Roe 2000): growing a crop, usually a legume, and then ploughing the entire crop back into the soil. The decomposition of the crop releases nitrogen into the soil, as well as slightly increasing its organic matter content (McLaren & Cameron 1996). However, the crop takes time to grow, further reducing the amount of land committed to producing direct short-term returns to the property.

All these techniques may be successful in restoring soil structure and organic matter, but not to the same extent as replacing lost soil organic matter with an amendment such as compost. Compost application is a much faster and efficient way of improving organic matter content and thus regaining soil structure in the long term.

Home gardeners readily accept the use of compost as a purchased amendment to their garden soils (Johnson 1998). Although the production of compost for commercial horticultural use is becoming popular in New Zealand, with many composting facilities being developed around the country, it seems there is considerable untapped potential. The benefits are being explored, and as has been the case overseas, some growers are achieving promising results with the use of compost applications.

Caution needs to be exercised when considering these results as the application rates of compost were in some cases well above the resource management consent restrictions set for Living Earth's Wellington biosolids compost in New Zealand. Although yield increases of 13% to 35% with compost additions have been reported in only a few of the papers presented, but majority of the publications on compost additions have concentrated on its impact in improving physical, biological and chemical conditions of soils. The results published are simply direct comparisons of one crop to another in either field plot or small-scale commercial production. The publications that looked at long-term benefits of compost application, did not consider yield enhancement at all or focussed only on the soil quality improvements achieved. The results of these studies were, therefore, of little practical use to determine the long-term gross margins from compost application.

4. Benefits of Compost Use: Grower Perceptions

The section presents the qualitative information collected from five growers in the Rangitikei, Manawatu and Horowhenua regions.

Grower A: a sole-proprietor involved in intensive market-garden production of two green crops in the Horowhenua region. He is a current user of compost, making applications both by hand and with a machine he has modified for applying compost. He has few quantified records of his production system and was not able to supply quantitative data about the benefits of compost. This grower was, however, able to make qualitative comments on the use of composts.

Grower B: a large-scale family partnership farming operation involved in cropping, sheep and beef cattle farming and forestry in the Rangitikei region. They have grown a range of crops for both processors and local and export fresh markets. They use composted materials supplied from other sources (not Living Earth). These composted materials are applied using their own, purpose-built equipment. These farmers do not use conventional fertilisers and have not done so for many years. Although they are able to quantify the various operations they perform and have quantified the yield they were not able to quantify the benefits obtained from composts over years. They were also not able to quantify the benefits to crop yield and quality they obtained from using composts.

Grower C: a sole trader involved in intensive market-garden production in the Horowhenua region. He uses compost that is currently applied both by hand and with his own equipment. This grower was not able to quantify either the increased costs or the benefits obtained by using composts but was able to supply qualitative data to support his use of compost.

Grower D: a family, vegetable-growing business specialising in the production of "greens". Located in the Manawatu region, these growers have used compost in the past but now use only conventional materials. They had vaguely quantified production information but not of the crops we had modelled. They were antagonistic to the use of compost and were also not forthcoming with data that they felt gave them competitive advantage over other growers.

Grower E: a mixed-cropping family farming operation in the Rangitikei region that focuses on producing potatoes for both process and local market supply. They do not use composts but are able to quantify the income and expenses associated with their production system. This grower was used to verify the potato Gross Margin Model.

Grower interviews
Growers who used compost instead of conventional fertilisers gave a number of reasons for doing so, although they had little in the way of quantitative evidence to support their claims. All the growers we interviewed felt they had improved yield as a result of applying compost. All compost users felt this improved yield was due to both the long- and short-term effects of using compost.

Grower A noted:

> *I've seen an improvement in my lettuce crops since I've been applying the compost...*
>
> *My lettuces are better quality and I get more out of a row than I used to.*

Grower C:

> *I reckon I get more off than I used to.*

Grower A has made observations similar to those of Grower B and in the literature that the quality of the product from compost-grown plants is better than from plants supplied with conventional nutrients. Unfortunately none of the growers had any record, such as improved TAG grades for fresh market-supplied produce or evidence of a reduction in penalties for produce supplied to processors.

All the growers believed that their crops were easier to grow as a result of using compost because the crops were better able to cope in adverse conditions. With one grower this was due to the ability of the crops to perform in adverse, clay soil, while another grower felt the crops grown in compost coped with climatic variability better than those produced on soils treated conventionally.

Grower B, who has sandy soils:

> *The soil seems to be coping better with the wet and the dry. Our yields haven't been as severely affected by the extremes in climate we have been experiencing lately, and I think that this is in part [due] to our additions of compost which have (?) improved the soil structure*

Grower A:

> *We had a drought last year, but despite this we still had a reasonable yield and crop, I think this was largely due to compost, and we didn't even have to irrigate as much. It really acts like a sponge in the soil.*

Growers see using compost as making it easier to produce crops. The soil is better able to sustain the crop; it has improved water-holding capacity. This means they can cultivate the ground in worse conditions than had been the case before they used compost.

Grower B:

> *We are able to get our gear onto the blocks for more of the year than we used to and we still don't seem to wreck things like we did, either.*

These benefits make the overall operation of a cropping or vegetable growing operation simpler. It makes performing and managing various operations simpler. Yet the precise value of such improvements is hard to quantify, and is not quantified by the growers.

Grower C, when questioned about the way in which he valued compost use, saw it as a commitment to improving the soil so the firm would be able to continue its high intensity style of production in the future. The grower felt that for this type of production compost was vital. If he was to cease market garden operations, however, he felt he would not require such an input:

> *If I ever stopped doing vegetables I'd put an end to the compost, I only need it because I want to keep on doing more of this.*

Growers who were not using compost were open to its use but had little or no idea what it might involve and had heard rumours of heavy metals issues. The potato grower, in particular, felt a local processor was really averse to its grower suppliers using biosolids compost as they had had past problems. When the processors' agronomist was approached he 1) did not wish to be quoted and, 2) said their clients have very low tolerance of any sort of contaminants in their crops and were generally averse to any use of biosolids as nutrients for crops supplied to them. Apart from general concerns and reference to a "grower in the Wairarapa" no specific instances of issues were provided.

The grower who had used compost previously but is now using conventional fertilisers had no specific detail of the issues that brought about that change except to say that a bad series of crops over a particular time frame were associated with trialling compost. This grower became quite agitated about this and the issue was not pursued.

From the discussions with the compost users and qualitative information received from them, it can be concluded that there are additional benefits from using compost. However, there is little information to put $$ values to these benefits. All Growers indicate that with the use of compost the crops were easier to grow and were better able to cope adverse conditions that prevailed.

5. Calculations of Gross Margin

The practical and financial implications of using compost

The focus of this report is the financial implications of compost use in vegetable cropping systems, as part of a drive to increase such use by farmers. The approach for this project therefore, has been to develop appropriate models for demonstrating the relative advantage of using biosolids compost in selected crops. The models applied here relate to the financial, grower level, performance of the crops using data from as many sources as possible. While the literature provided limited information, interviews with the growers and field representative were also invaluable in providing a real-world context for the information collected. While the growers who use/d compost were being interviewed to collect financial information, notes were also taken of other factors related to the beneficial use of compost. Such factors were thought to have some potential use in evaluating factors growers considered important in their adoption processes.

The selected modelling approach was Gross Margins Analysis. Gross margin budgets are useful, first step, in comparing the profitability of different enterprises (Burtt 2002). With this approach, fixed costs are ignored and the financial implications of making small changes in an existing system, such as a vegetable production unit using conventional fertilisers, can be readily evaluated. The level of output is based on the level of input. When grower-level information is used as an input, grower-level information is produced.

A gross margin (Gross Margin) is calculated by deducting the sum of the direct costs (DC) from the revenue (TR) associated with a given enterprise:
Gross Margin = TR-DC

For comparison purposes the Gross Margin is expressed in terms of a limiting resource (such as land, or labour) on a fixed time basis, usually 1 year. This allows two different enterprises to be easily compared based on their financial merits. Gross Margin can also be used in situations where there is uncertainty about the data being used.

Gross Margins are published by organisations such as the New Zealand Vegetable Growers Federation and the Ministry of Agriculture and Forestry to enable interested parties (vegetable growers, farmers, farm managers, field representatives, farm consultants, etc.) to compare the performance of various crops under standard conditions. These published Gross Margins verified for local Manawatu and Horowhenua conditions, form the basis of the Gross Margins used for the “conventional” fertiliser part of this report’s comparisons.

By changing the costs and revenues using information from various sources a modified Gross Margin has been developed that can then be used to compare the performance of crops grown in either conventional or compost nutrient supply situations.

Information was also obtained from a ground-spreading contractor (only one of three contractors approached was able to supply a charge-out rate for compost application) and other relevant "experts", including Living Earth sales staff, an agronomist for a local food processor, and staff from Massey University's Institute of Natural Resources and from Landcare Research.

For this study it was assumed that the application rate of compost was 12.5t/ha (fresh weight basis) i.e. the Wellington resource consent limit for Living Earth's Biosolid compost. Nutrients from composts and conventional fertiliser sources have been assumed to be equally available. Based on the amount of nutrient (N:P:K composition) in the compost, additional conventional fertilisers have been costed into the Gross Margin to ensure the nutrient levels are the same in both the conventional and compost situations. This is based on the wet compost having 50% moisture content and, therefore, 50% of the nutrient content of dry compost by weight. The average nutrient composition of fresh compost used in these calculation was N:P:K:2.20:1.00:0.56 (George Fietje, pers. comm.).

As pointed out above, Gross Margin can also be used where the data are uncertain. A sensitised Gross Margin can be developed for ranges in costs or items used to construct the budgets. For instance, there is uncertainty in all cases about the cost for spreading compost – the rate of $20/t seems low. If the information we have is wrong and the cost is, for example, $30/t or even $40/t, the sensitised Gross Margin allows this question to be answered.

Similarly, as there is a paucity of research on the incremental yield likely to be obtained by using compost, the range of likely yield increases has been modelled with a sensitised Gross Margin. The outcomes, which result from a 30%, 20%, or 10% yield increase, can be compared with a status quo position.

6. Results of Gross Margins Analyses and Discussion

On balance, the literature supports an improvement in yield of the order of 10% from using compost as a nutrient source (Warman 1998; Maynard 1995). One author has reported that improvements as high as 30% can be obtained in some situations (Logsdon 1993). While most authors have simply reported on an unspecified yield improvement when compost is substituted for conventional fertilisers, Shepherd et al. (2001) reported a yield depression. Others (Sikora 1998; Rosen et al. 1993) have suggested compost was not able to supply sufficient nutrients for optimum crop growth. Although growers interviewed were not able to confirm these incremental improvements in performance with hard data, the anecdotal evidence they provided supported improvements in crop performance.

Table 1 presents the Gross Margins that result for each crop from a status quo position and show a 10%, 20% or 30% improvement in yield result from using compost and balancing the nutrients supplied with the conventional position.

Note: As the quantity of nutrients supplied to the composted crop matches the quantity supplied when only chemical fertilisers are used, it has been assumed there will be no yield depression when such a compost and chemical fertiliser application is made.

Table 1. Gross Margins/ha derived from average production and by making parametric changes from status quo (+10%, +20% and +30%) to the yield for cauliflower, potato, and sweetcorn for compost-grown crops compared with crops grown with conventional nutrient sources.

Crop (duration)	Conventional base yield	Supplemented compost base yield	+10% yield	+20% yield	+30% yield
Cauliflower	$2,093.43	$2,017.47	$2,734.67	$3,451.87	$4,169.06
(120day)	(575 crates)	(575 crates)	(632 crates)	(690 crates)	(747 crates)
Potato	$997.70	$504.57	$952.57	$1,400.57	$1,848.57
(120day)	(35 t)	(35 t)	(38.5 t)	(42.0 t)	(45.5 t)
Sweetcorn	$678.40	$158.40	$387.90	$617.40	$846.90
(120day)	(17t)	(17t)	(18.7t)	(20.4 t)	(22.10 t)

The above Gross Margins assume the only income derived from a particular block of land is associated with the crop to which the compost is applied. In fact, for some of the crops above, growers would plant another crop to follow; depending on the approach to providing nutrition for the next crop in the rotation, additional financial benefits could be expected.

In all cases, if there is no improvement in yield the compost Gross Margin is lower than that obtained from using conventional fertilisers. The Gross Margin is very sensitive to changes in yield; any improvement in yield obtained from the use of compost will improve the Gross Margin significantly. Only in the case of cauliflower does a 10% increase in yield with compost exceed the Gross Margin of the conventionally fertilised crop. In potatoes the improvement in yield with compost needs to be above a 10% level for the Gross Margin to be better than conventional. In sweetcorn the model shows a more than 20% yield improvement is required for the Gross Margin to exceed the conventional base situation. The reason for these differences was the large variation in the cost of purchasing and applying conventional fertilisers, compared with compost.

The profitability of using compost is also affected by the cost of compost and the cost of applying it. The following tables (Tables 2 & 3) compare the effects of changes in the cost of spreading the compost (Table 2) and the cost of acquiring the compost delivered to the property (Table 3).

Note: as the prices supplied included delivery to a central Manawatu site, the cost of compost purchase and the cartage charge have been amalgamated.

There are small differences among the Gross Margin obtained for all crops with the compost spreading cost between $10/t and $30/t, and the greatest difference is of $250/ha (Table 2). These calculations indicate the Gross Margin is relatively insensitive to compost spreading cost. Growers could spend up to 50% more or 50% less than allowed in the base position with minimal difference to the Gross Margin for their crop. Therefore, due to its minimal effect a lack of site-specific information for the compost spreading cost is not vital in calculating the Gross Margin for these crops.

Table 2. Effects of varying the cost of spreading compost on the Gross Margins of cauliflower, potato and sweetcorn, assuming compost provides a 10% improvement in yield on a hectare basis.

Cost of spreading compost	Cauliflower (632 crates/ha)	Potato (38.5t/ha)	Sweetcorn (18.7t/ha)
$10/t	$2,859.67	$1,072.57	$512.90
$15/t	$2,797.14	$1,012.57	$450.40
$20/t (Base level)	**$2,734.67**	**$952.57**	**$387.90**
$ 25/t	$2,672.17	$892.57	$325.40
$30/t	$2,609.67	$832.57	$262.90

Model calculations also show similar effects for the cost of compost supply and delivery (Table 3). The Gross Margin is relatively insensitive to the cost of compost. Although it may be a major concern to growers, variation in yield and the price obtained for it are much more likely to affect the Gross Margin. For cauliflowers, the crop with the highest Gross Margin, the difference between the Gross Margin when compost cost is $35/t and $65/t, is $375/ha (compost applied at the 12.5t/ha rate), which is less than the impact of a 10% change in yield.

Table 3. Effects of varying the cost of supply of compost on the Gross Margins for cauliflower, potato and sweetcorn based on a 10% better yield than standard.

Cost of supplying compost	Cauliflower (632 crates/ha)	Potato (38.5t/ha)	Sweetcorn (18.7t/ha)
$35/t	$2,859.67	$1,072.57	$512.90
$45/t (Base level)	**$2,734.67**	**$952.57**	**$387.90**
$55/t	$2,609.67	$832.57	$262.90
$65/t	$2,484.67	$712.57	$137.90

The Gross Margins analysis derives the relative financial advantage from using composts for the crop they are calculated for. The use of this or any other tool to derive a financial benefit depends on having accurate input information to drive it. While there was very little quantitative data available for the above analyses, growers were able to provide qualitative information to support their decision to use composts. Agricultural change literature reports that farmers or growers evaluate new technologies in terms of various attributes of each innovation. The financial advantage as derived in the Gross Margins is just one of these. Rogers (1983) lists five attributes of innovations farmers use to evaluate technologies:

Relative advantage: the extent to which an innovation is better than its predecessor. Often people think only of the financial advantage of any given technology but improved ease of farm operation and other less direct benefits may be considered.

Trialability: the degree to which a technology can be experimented with on a limited basis.

Observability: the degree to which the technology and its use are visible. Although Biosolids compost has been used on some sites it is not widely accessible to the community.

Complexity: is the extent to which farmers perceive both using the technology and managing the effects of using the technology, to be complex. .

Compatibility: how well using the technology sits with the values and past experiences of the potential adopter.

While the financial evaluation in the Gross Margins relates to part of Rogers (1983) relative advantage component of technologies, the qualitative information collected for this research relates to this and other attributes of innovations.

Gross Margins analyses demonstrate there is likely to be a relative advantage for growers of cauliflowers and potatoes who use compost and chemical fertilisers to ensure the nutrients supplied match those normally applied through chemical fertilisers alone; however, there are other factors that make compost a compatible part of their vegetable production system. Factors such as those described by growers, (see Section 4), need to be taken into account while considering the results of the Gross Margins modelling.

The lack of directly observed and measured differences in production is a hindrance to grower understanding and hence to adoption of compost as a soil amendment. While the Gross Margins have been developed using realistic information, no quantitative data came from a grower who uses composts. To allow growers at large to see the use of compost and to see that it can readily be incorporated into their systems, a much better set of data needs to be collected and used. With the availability of such data, growers will be better able to evaluate the use of compost on their properties. They will be able to evaluate it in terms of its compatibility with their operation, as well as the relative advantage of using it over time – this will be visible in both direct improvements in Gross Margins but presumably in the capital value of their land as the physical benefits achieved are turned into improved performance.

Biosolids compost is an approach growers can use to improve their bottom line, even in the first season it is applied. The benefits, however, far exceed those derived from the first year's application: should these be quantified, the use of such composts would be far more attractive to growers. Quantifying these benefits in financial terms is a major priority.

7. Conclusions and Recommendations

Composting is a sustainable practice that transforms organic waste products into a valuable commodity that can be used by many markets. This waste would normally be land filled, causing pollution problems and forcing regulatory bodies to reassess the way in which municipal waste is handled. It is seen by many as a way to close the recycling loop and return the nutrients in organic waste back to the soil.

Intensive cropping systems and excessive cultivation have degraded many New Zealand arable soils, a limited resource of our total land area basis. Heavy applications of synthetic fertilisers have also caused pollution problems in ground water supplies. To protect the soils growing properties, and to ensure New Zealand food and crop production can be continued in the future, growers must adopt sustainable growing practices, including compost addition.

The risks involving heavy metal accumulation and their bioavailability due to long-term use of composts containing biosolids need further research. Growers must be assured the products they are using are safe, and will not deter any potential customers or selling markets. The compost producers, in this case Living Earth, must continue to produce high-quality, safe composts to reassure potential compost users, and to maintain the reputation of the compost industry.

From the discussions with the users of compost and qualitative information received from them, it can be concluded that there are benefits from using compost. However, there is little information to put $$ values to these benefits. All Growers indicate that with the use of compost the crops were easier to grow because the crops were better able to cope in adverse conditions that prevailed.

In the Gross Margins produced for this report the addition of compost resulted in higher gross margins for some of the crops only when an improvement in yield (10 to 30%) was achieved. The reason for these differences was the large variation in the cost of purchasing and applying conventional fertilisers, compared with compost. The sensitivity tables produced from the Gross Margin budgets showed the financial viability of compost-amended growing systems was highly sensitive to changes in yield and the price received for the crops, yet little research has reported on the effects prolonged compost application on these. The financial viability of compost was much less sensitive the price of compost or the costs of spreading it. Therefore, a lack of site-specific information for the compost spreading cost is not vital in calculating the Gross Margin for these crops.

Compost plays a vital role as a soil conditioner through its influence on most physical, biological and chemical processes in the soil. These processes collectively determine 'soil health'. Therefore in cultivated systems, productivity and sustainability are directly related to soil health. Continued research into the benefits of using composts in New Zealand must also be performed. Data from overseas show compost use can be valuable in intensive production systems; yet financial data and the information to derive it are seldom reported. Moreover, due to the differences in soil type, climate, compost composition and growing system, results obtained overseas will be difficult to extrapolate to New Zealand conditions. To assess accurately the financial benefits of using composts, more reliable yield data must be obtained. Long-term field trials need to be conducted to understand the improvements in soil structure that can be achieved from using composts, and to assess the impacts these improvements have on yield.

Furthermore, despite claims that the quality of produce grown in compost system is "better" than that produced conventionally, organoleptic qualities are still largely overlooked in terms of price setting in New Zealand produce marketing. Once growers' produce achieves certain quality criteria their rewards are derived from the yield of the crop they produce. Without more extensive yield results, it may be difficult to sell compost use to growers on sustainability benefits alone.

Growers need to be made aware that compost addition is not a substitute fertiliser but a soil conditioner. Through decomposition it can potentially supply some of the macronutrients needed for plant growth. Therefore, the use of compost in combination with the inorganic fertilisers is likely to be necessary to achieve yield and sustainability benefits.

8. Key Recommendations

- Quantify improved yields from compost application for New Zealand context on crop basis, and consider long-term improvements to crops and crop rotations;
- Obtain better information about costs associated with applying biosolids compost (this should include both direct costs associated with each crop and indirect costs and benefits associated with items such as capital improvements and necessary purchases).

Note: Long-term field trials should be established with the growers who maintain a recording system capable of providing the relevant information. Small-scale vegetable growers do not have this capability because their operations are too small and intensive for this to be accomplished easily. Large-scale cropping farmers use models such as Gross Margins to evaluate their operations now. Having a farmer who is accustomed to collecting and using such information would simplify the task.

Trials should be established on a mixed-cropping farm to evaluate the benefits of biosolids compost application over a 5- to 6-year period.

9. Bibliography

Agboola, A.A. 1978: Influence of soil organic matter on cowpea's response to N fertilizer. *Agronomy Journal 70:* 25–28.

Ball, B.C.; Campbell, D.J.; Henshall, J.K.; Sullivan, M.F.O. 1997: Soil structural quality, compaction and land management. *European Journal of Soil Science 45:*3–13.

Burtt, E.S. *ed*. 2002. Financial budget manual. Lincoln University, New Zealand, Lincoln University Farm Management Group Applied Management and Computing Division. Pp. B67–C57.

Committee on the use of treated municipal wastewater effluents and sludge in the production of crops for human consumption. 1996: Use of reclaimed water and sludge in food crop production. Washington, National Academy Press. Pp. 155–157.

Edmeades, D.C. 1999: The long-term effects of manures and fertilisers on soil productivity and quality – a Review. Ravensdown Report. 21 p.

Francis, G.S.; Tabley, F.J.; White, K.M. 1999: Restorative crops for the amelioration of degraded soil conditions in New Zealand. *Journal of Soil Research 37:* 1017–1034.

Geldreich, E.E. 1990: Microbiological quality of source waters for water supply. *In*: McFeters, G.A. e*d.* Drinking water microbiology. New York, Springer-Verlag. Pp. 3–31.

Haynes, R.J. 1999: Size and the activity of soil microbial biomass under grass arable management. *Biology and Fertility of Soils 30:* 210–216.

Haynes, R.J.; Beare, M.H. 1997: Influence of six crop species on aggregate stability and some labile organic matter fractions. *Soil Biology and Biochemistry 29:* 1647–1653.

Haynes, R.J.; Francis, G.S. 1990: Effects of mixed cropping farming systems on changes in soil properties on the Canterbury Plains. *New Zealand Journal of Ecology 14:*73–82.

Haynes R.J.; Swift, R.S. 1990: Stability of soil aggregates in relation to organic constituents and soil water content. *Journal of Soil Science 41:* 73–83.

Haynes, R.J.; Tregurtha, R. 1999: Effects of increasing periods under intensive vegetable production on biological, chemical and physical indices of soil quality. *Biology and Fertility of Soils 28:* 259–266.

Haynes, R.J.; Swift, R.S.; Stephen, R.C. 1991: Influence of mixed cropping rotations (pasture-arable) on organic carbon content, water stable aggregates and clod porosity in a group of soils. *Soil and Tillage Research 19:* 77–87.

Hormann, C.M.; Clapp, C.E.; Dowdy, R.H.; Larson, W.E. Duncomb, D.R.; Halbach, T.R.; Polta, R.C. 1994: Effect of Lime-cake municipal sewage sludge on corn yield, nutrient uptake, and soil analyses. *In*: Clapp, C.E.; Larson, W.E.; Dowdy, R.H. e*ds* Sewage sludge: Land utilization and the environment. Madison, USA, SSSA Miscellaneous. Pp. 173–181.

Hornick, B.; Parr, J.F. 1987: Restoring the productivity of marginal soils with organic amendments. *American Journal of Alternative Agriculture 2(2)*: 64–68.

Johnson, K. 1998: Balancing markets with compost production. *BioCycle 39(6)*: 48–51.

Johnston, A.E. 1993: Significance of organic matter in agricultural soils. *In* Beck, A.J. et al e*ds* Organic ubstances in soil and water: Natural constituents and their influences on scontaminant behaviour. Cambridge, The Royal Society of Chemistry. Pp. 3-18.

Living Earth. 1997: Wellington Biosolids Project. Resource consent applications and assessment of environmental effects for the use of biosolids compost on land. Living Earth Joint Venture. Pp. 17–51.

Living Earth. 2003: Biowaste information. http://www.livingearth.co.nz (22 December 2003).

Logsdon, G. 1993: Beneficial biosolids. *Biocycle 34(2)*: 42–44.

Maynard, A.A. 1995: Increasing tomato yields with MSW compost. *Biocycle 36(4)*: 104–106.

McLaren, R.G.; Cameron, K.C. 1996: Soil science: Sustainable production and environmental protection. 2nd Ed. Auckland, Oxford University Press. Pp. 83–277.

MfE 2002: Technical manual on biosolids. Ministry for the Environment, PO Box 10362, Wellington.

Naylor, L.M.; Wark, R.; Allen, N.; Perkins, D. 2000. In-vessel system used at biosolids co-composting site. *Biocycle 41(6)*: 76–78.

NZWWA 2003: Guidelines for the safe application of biosolids to land in New Zealand. New Zealand Waste Water Association, PO Box 1316 Wellington.

Olsen, S.R. 1986: The role of organic matter and ammonium in producing high corn yields. *In* Chen, Y.; Avnimelech, Y. *eds* The role of organic matter in modern agriculture. Doedrecht, Martinus Nijhofft. Pp. 29–54.

Ozores-Hampton, M.; Peach, D.R.A. 2002: Biosolids in vegetable production systems. *HortTechnology 12(3)*: 336–340.

Ozores-Hampton, M.; Schaffer, B.; Bryan, H.H.; Hanlon. E.A. 1994: Nutrient concentrations, growth, and yield of tomato and squash in municipal solid-waste-amended soil. *HortScience 29(7)*: 785–788.

Ozores-Hampton, M.; Obreza, T.A.; Hochmuth, G. 1998: Using composted wastes on Florida vegetable crops. *HortTechnology 8(2)*: 130–137.

Rebufetti, A.; Lubunora, D. 1982: Wheat yield in northeastern Uruguay in relation to NPK fertilizers, soil organic matter and climatic conditions. *In:* Cerri, C.C. *ed*. Regional Colloquium on Soil Organic Matter studies. Sao Paolo, Promocet. Pp. 117–122.

Roe, N. 1998: Municipal waste compost production and utilization for horticultural crops: Introduction to the colloquium. *HortScience 33(6)*: 931.

Roe, N. 2003: Using composts in commercial vegetable and fruit operations. <http://aggie-horticulture.tamu.edu/vegetable/steph/compost.html> (8 December 2003).

Rogers, E.M. 1983: Diffusion of Innovations (3rd Ed) The Free Press: New York.

Rosen, C.J.; Halbach, T.R.; Swanson, B.T. 1993: Horticultural uses of municipal solid waste composts. *HortTechnology 3(2)*: 167–173.

Saggar, S.; Yeates, G.W.; Shepherd, T.G. 2001: Cultivation effects on soil biological properties, microfauna and organic matter dynamics in Eutric Gleysol and Gleyic Luvisol soils in New Zealand. *Soil and Tillage Research 58:* 55–68.

Schaepf, H. 1967: Relationships between the humus content of soil and crop yields in a long-term fertilizer trial. *Albrecht Thaer Archiv 11:*133–141.

Schreeg, T.M.; Jarrett III, D.L. 1996: Biosolids cut fertilizer costs by $200 an acre. *Biocycle 37(10)*: 69–71.

Scrimgeour, F.G.; Shepherd, T.G. 1998: The economic of soil structural degradation under cropping: some empirical estimates from New Zealand. *Australian Journal of Soil Research 36:* 831–840.

Shepherd, T.G. 1992: Sustainable soil-crop management and its economic implications for grain growers. *In*: Henrique, P.R. *ed*. Sustainable land management: Proceedings of the International Conference on Sustainable Land Management, Napier, 1991. Napier, Hawke's Bay Regional Council. Pp. 141–152.

Shepherd, T.G.; Ross, C.W.; Basher, L.R.; Saggar, S. 2000: Soil management guidelines for sustainable cropping. Christchurch, Manaaki Whenua Press. 26 p.

Shepherd, T.G.; Saggar, S.; Newmann, R.H.; Ross, C.W.; Dando J.L. 2001: Tillage-induced changes to soil structure and organic carbon fractions in New Zealand soils. *Australian Journal of Soil Research 39:* 465–489.

Sikora, L.J. 1998: Nitrogen availability from composts and blends of composts and fertilizers. *In:* Szmidt, R.A.K. *ed.* Proceedings of the International Symposium on Composting and the Use of Composted Materials for Horticulture *Acta Horticulturae 469.* Lueven, ISHS Publishing. Pp. 343–351.

Smith, S.R.; Hall, J.E.; Hadley, P. 1992: Composting sewage wastes in relation to their suitability for use as fertilizer materials for vegetable crop production. *In:* Balis, C. *ed.* International Symposium on Compost Recycling of Wastes *Acta Horticulturae 302.* Wageningen, ISHS Publishing. Pp. 203–215.

Sparling, G.P.; Shepherd, T.G.; Kettles, H.A. 1992: Changes in soil organic C, microbial biomass and aggregate stability under continuous maize and cereal cropping, and after restoration to pasture from the Manawatu region, New Zealand. *Soil and Tillage Research 24:* 225–241.

Stevenson, F.J. 1994: Humus chemistry: genesis, composition, reactions. 2nd Ed. New York, Wiley-Interscience.

Wang, H.; Magesan, G.N. 2003: Biosolids use increases pine production. *Biocycle 44(6)*: 56.

Warman, P.R. 1998: Results of the long-term vegetable crop production trials: conventional vs. compost amended soils. *In*: Szmidt, R.A.K. *ed.* Proceedings of the International Symposium on Composting and Use of Composted Materials for Horticulture *Acta Horticulturae 469.* Lueven, ISHS Publishing. Pp. 333–341.

Zhang, M.; Heaney, D.; Solberg, E.; Heriquez, B. 2000: The effect of MSW compost on metal uptake and yield of wheat, barley and canola in less productive farming soils of Alberta. *Compost Science and Utilization 8(3)*: 224–23.

10. Appendices

Appendix 1. Assumptions

The Gross Margins have been developed from the New Zealand Vegetable and Potato Growers Federation models verified using both grower and other “expert” information to bring them into line with current position in the Rangitikei, Manawatu and Horowhenua.

For convenience, land and interest costs have not been included in the Gross Margins calculations. It has been assumed all crops have approximately the same duration in the ground and the performance of each crop is independent of where it occurs in a grower’s rotation.

General assumptions:
Information about the costs and returns of the compost-based nutrient system were derived from interviews with Growers A, B, and C, and from the following related sources:

1. The rate of compost application, 12.5 t/ha was derived from the maximum rate allowed in NZ from Living Earth’s 1997 “Wellington’s Biosolids Project resources consent application.

2. The cost of compost application is based on what a contractor would charge to do the job. Neither of the Vegetable growers contacted had records of what they spent on the job and were vague about the real costs involved in spreading compost and in building/modifying equipment to carry out the job. To simplify the analysis at this stage a contract rate will be used. For this reason $20/t, as quoted by Mr George Feitje, is used as the cost for spreading compost.

   (None of the Manawatu or Horowhenua based fertiliser spreading contractors was prepared to supply a rate for spreading compost. However, Grower B believes it costs him around $60 a hectare to spread similar materials with his own equipment).

3. The average N:P:K composition of dry compost applied is 2.20:1.00:0.56, based on a range of values supplied by Mr George Feitje. The fresh compost contains about 50% moisture. To convert to dry weight, the fresh weight is multiplied by 50%.

4. The fertiliser regime for all crops has been based on application of sufficient compost to match the N, P, and K supplied by the conventional fertilizers. If the amount of compost required exceeds 12.5 t/ha/yr, as is the case in potato and cauliflower production, the shortfall has been made up with appropriate conventional fertilisers.

5. No price advantage is obtained by using compost to grow the crops as the crop either does or does not make the quality parameters supplied by the markets. Growers who had used compost were not able to quantify improvements in product quality as a result of their use of compost. In the case of process-crop farmers, should such differences have occurred and been acted on, differences in payouts would have been observed. However, none of the growers interviewed were in this position.

6. Changes to the nutrient supply system, that is, substituting compost for chemical fertilisers, are assumed to have made no difference to other parts of the system. In fact, this may not be the case as, herbicide efficacy for instance may be impaired by the addition of extra organic matter to the soil.

Crop-specific assumptions:

Sweetcorn

7. For simplicity a process sweetcorn crop is used as the comparison model. Market-garden growers were unable to supply sufficient information about production of fresh market crops to allow a robust model to be developed.

Cauliflower

8. Information for the cauliflower system was based on fresh market supply on an average price of $0.93 a curd. This is an average price for curds over a season. As the returns for cauliflower are extremely variable, this price is only indicative.

9. Information used to build this Gross Margin was derived more from grower interviews than from the crop models supplied from VegFed, as the supplied model was very different from the growers' current situation. Grower information is assumed to be correct and can be used as the basis of the crop model.

Potato

10. The crop model is based on production of fresh market potatoes from un-irrigated land to a local packer.

Gross Margin Calculations

Appendix 2. Gross margin budgets for sweet crops

Crop: Sweetcorn (conventional)

Preparation	Unit Rate $	
Spray pasture	44.50	ha
Glyphosate	9.00	l
Direct drilling	90.00	ha
Sowing		
Seed sowing incl fert appl.	85.00	ha
Seed cost	30.00	kg
Crop Master 15:10:10	540.00	t
Cultivate and side dress	44.50	ha
Urea	430.00	t
Crop Maintenance		
Pre emergence spray	32.50	ha
Trophy	16.00	l
Soil incorporation	100.00	ha
Post emergence spray	35.00	ha
Karate	540.00	l
Weed control Atrazine	8.00	l
Aerial Application	35.00	ha
Carbaryl Flo	19.00	l
Inter-row cultivation	38.00	ha
Land Maintenance		
flail stubble	72.00	hr
Harvesting		
Heading	230.00	ha*

Sweetcorn (compost)

Preparation	Unit Rate $	
Spray pasture	44.50	ha
Glyphosate	9.00	l
Direct drilling	90.00	ha
Sowing		
Seed sowing incl fert appl.	85.00	ha
Seed cost	30.00	kg
Compost		
Compost & cartage	45.00	t
Spreading	20.00	t
Crop Maintenance		
Pre emergence spray	32.50	ha
Trophy	16.00	l
Soil incorporation	100.00	ha
Post emergence spray	35.00	ha
Karate	540.00	l
Weed control Atrazine	8.00	l
Aerial Application	35.00	ha
Carbaryl Flo	19.00	l
Inter-row cultivation	38.00	ha
Land Maintenance		
flail stubble	72.00	hr
Harvesting		
Heading	230.00	ha*

Growing Costs Operation (Conventional)	**Rate**		**Total cost $ per ha**
Preparation			
Spray pasture	1		44.50
Glyphosate	2.5	l/ha	22.50
Direct drilling	1		90.00
Sowing			
Seed sowing incl fert appl.	1		85.00
Seed	12	kg/ha	360.00
Crop Master 15:10:10	0.3	t/ha	162.00
Cultivate and side dress	1		44.50
Urea	0.2	t/ha	86.00
Crop Maintenance			
Pre emergence spray	1		32.50
Trophy	6	l/ha	96.00
Soil incorporation	1		100.00
Post emergence spray	1		35.00
Karate	0.04	l/ha	21.60
Weed control Atrazine	3	l/ha	24.00
Aerial Application	1		35.00
Carbaryl Flo	2	l/ha	38.00
Inter-row cultivation	1		38.00
Land Maintenance			
flail stubble	1	hr	72.00
Harvesting			
Heading	1		230.00
TOTAL GROWING COSTS			**1616.60**
REVENUE			
Price paid per tonne			135.00
Crop yield (tonnes per hectare)			17.00
TOTAL REVENUE			**2295.00**
(Less growing costs)			
GROSS MARGIN			**$678.40**

Growing Costs Operation (Compost)	Rate		Total cost $ per ha
Preparation			
Spray pasture	1		44.50
Glyphosate	2.5	l/ha	22.50
Direct drilling	1		90.00
Sowing			
Seed sowing incl fert appl.	1		85.00
Seed	12	kg/ha	360.00
Crop Master 15:10:10			0
Cultivate and side dress	1		0
Compost			0.00
Compost	12.5	t/ha	562.50
Cartage and spreading	12.5	t/ha	250.00
Crop Maintenance			
Pre emergence spray	1		32.50
Trophy	6	l/ha	96.00
Soil incorporation	1		100.00
Post emergence spray	1		35.00
Karate	0.04	l/ha	21.60
Weed control Atrazine	3	l/ha	24.00
Aerial Application	1		35.00
Carbaryl Flo	2	l/ha	38.00
Inter-row cultivation	1		38.00
Land Maintenance			
flail stubble	1	hr	72.00
Harvesting			
Heading	1		230.00
TOTAL GROWING COSTS			**2136.60**
REVENUE			
Price paid per tonne			135.00
Crop yield (tonnes per hectare)			17.00
TOTAL REVENUE			**2295.00**
(Less growing costs)			
GROSS MARGIN			**$158.40**

Appendix 3. Gross margin budgets for potato crops

Crop: Potato (conventional)

	Unit Rate $	
Preparation		
Sub-soil	90.00	ha
Disc	55.00	ha
Plough	120.00	ha
Power harrow	110.00	ha
Fertiliser		
Crop 15	475.30	t
Potassium sulphate	691.00	t
Urea	430.00	t
Spreading & cartage	40.00	ha
Planting		
Seed potatoes	450.00	t
Planting	250.00	ha
Crop Maintenance		
Herbicide application	32.50	ha
Insecticide application	32.50	ha
Fungicide application	32.50	ha
Monceren	35.00	kg
Carbaryl	19.00	l
Sencor	92.00	kg
Mancozeb	9.50	kg
Ridomil	49.42	kg
Moulding	65.00	ha
Harvest		
Dessication (Reglone)	20.00	l
Harvesting	30.00	t
Postharvest		
Freight	22.00	t
Land lease	0.00	ha

TOTAL GROWING COSTS		**Rate**		**Total Cost $ per ha**
Preparation				
Sub-soil		1		90.00
Disc		1		55.00
Plough		1		120.00
Power harrow		1		110.00
TOTAL PREP				**375.00**
Fertiliser				
Cropmaster 15:10:10		1	t/ha	475.30
Potassium sulphate		0.25	t/ha	172.75
Urea		0.2	t/ha	86.00
Spreading & cartage				40.00
TOTAL FERT		**1.45**	**t/ha**	**774.05**
Planting				
Seed potatoes		2.1	t/ha	945.00
Planting		1		250.00
TOAL PLANT				**1195.00**
Crop Maintenance				
Herbicide Application		1		32.50
Sencor	1 x	0.3	kg/ha	27.60
Insecticide application		2		65.00
Carbaryl	2 x	3	l/ha	114.00
Fungicide application		4		130.00
Monceren		2	kg/t seed	147.00
Mancozeb	1 x	2	kg/ha	19.00
Ridomil	3 x	2.5	kg/ha	370.65
Moulding		2		130.00
TOTAL MAIN.				**1035.75**
Harvest				
Dessication application		1		32.50
Reglone		3.5	l/ha	70.00
Harvest		35.00	t	1050.00
TOAL HARV.				**1152.50**
Transport				
Freight				770.00
TOTAL FRGT.				**770.00**
TOTAL GROWING COSTS				**5,302.30**

Potato (compost)

	Unit Rate $	
Preparation		
Sub-soil	90.00	ha
Disc	55.00	ha
Plough	120.00	ha
Power harrow	110.00	ha
Compost		
Compost & cartage	45.00	t
Spreading	20.00	t
Planting		
Seed potatoes	450.00	t
Planting	250.00	ha
Crop Maintenance		
Herbicide application	32.50	ha
Insecticide application	32.50	ha
Fungicide application	32.50	ha
Monceren	35.00	kg
Carbaryl	19.00	l
Sencor	92.00	kg
Mancozeb	9.50	kg
Ridomil	49.42	kg
Moulding	65.00	ha
Harvest		
Dessication (Reglone)	20.00	l
Harvesting	30.00	t
Postharvest		
Freight	22.00	t
Land lease	0.00	ha

TOTAL GROWING COSTS		**Rate**		**Total Cost $ per ha**
Preparation				
Sub-soil		1		90.00
Disc		1		55.00
Plough		1		120.00
Power harrow		1		110.00
TOTAL PREP				**375.00**
Fertiliser				
Cropmaster 15:10:10		0.71	t/ha	337.46
Potassium Sulphate		0.22	t/ha	149.72
Spreading & Cartage				40.00
Total fertiliser				487.18
Compost				
Compost and cartage		12	t/ha	540.00
Spreading		12	t/ha	240.00
TOTAL COMP				**780.00**
Planting				
Seed potatoes		2.1	t/ha	945.00
Planting		1		250.00
TOTAL PLANT				**1195.00**
Crop Maintenance				
Herbicide Application		3		97.50
Sencor	1 x	0.3	kg/ha	27.60
Insecticide application		1		32.50
Carbaryl	2 x	3	l/ha	114.00
Fungicide application		3		97.50
Monceren		2	kg/t seed	147.00
Mancozeb	1 x	2	kg/ha	19.00
Ridomil	3 x	2.5	kg/ha	370.65
Moulding		2		130.00
TOTAL MAIN.				**1035.75**
Harvest				
Dessication application		1		32.50
Reglone		3.5	l/ha	70.00
Harvesting		35.00	t	1050.00
TOAL HARV.				**1152.50**
Transport				
Freight				770.00
TOTAL FRGT.				**770.00**

Appendix 4. Gross margin budgets for cauliflower crops

Crop: Cauliflower (conventional)

Preparation	Unit Rate $	
Plough	120.00	ha
Rotary hoe	105.00	ha
Level	40.00	ha
Base dressing application	40.00	ha
Lime	17.00	t
Superphosphate	180.00	t
Potassium Sulphate	691.00	t
Planting		
Cell transplants	12.00	per 144 tray
Additional labour	10.00	hour
Crop Maintenance		
Herbicide application	32.50	ha
Lasso	15.00	l
Side dressing application	35.00	ha
Nitrophoska 12.10.10	589.00	t
Inter-row cultivation	38.00	ha
Insecticide application	32.50	ha
Karate Zeon	472.00	l
Kocide	15.00	kg
Harvesting		
Labour	11.00	hour
Post harvest		
Packaging	1.00	crate
Caulis Per Crate	16.00	curds

GROSS MARGIN CAULI

TOTAL GROWING COSTS	Rate		Total Cost $ ha
Preparation			
Plough	1		120.00
Rotary hoe	3		315.00
Level	1		40.00
Base dressing application	1		40.00
Lime	3	t/ha	51.00
Superphosphate	2	t/ha	360.00
Total Preparation			**926.00**
Planting			
Cell transplants	174	trays	2088.00
Additional labour	3 people	12 hours	360.00
Total planting			**2448.00**
Crop Maintenance			
Herbicide application	1		32.50
Lasso	6	l/ha	90.00
Side dressing application	1		35.00
Nitrophoska 12.10.10	2	t/ha	1178.00
Inter-row cultivation	2		76.00
Insecticide application	3		97.50
Karate Zeon	0.4	l/ha	188.80
Kocide	0.45	kg/ha	6.75
Total Crop Maintenance			**1704.55**
Harvesting			
Labour	0.157	hr/crate	993.025
Total Harvesting			**993.025**
Post harvest			
Packaging	575	crates	575
			575
TOTAL GROWING COSTS			**6646.58**
REVENUE			
Yield (curds per ha)			9200
Yield (crates per ha)			575
Yield (tonnes per ha)			23

Crop: Cauliflower (compost)

Preparation	Unit Rate $	
Plough	120.00	ha
Rotary hoe	105.00	ha
Level	40.00	ha
Compost		
Compost & cartage	45.00	t
Spreading	20.00	t
Planting		
Cell transplants	12.00	per 144 tray
Additional labour	10.00	hour
Crop Maintenance		
Herbicide application	32.50	ha
Lasso	15.00	l
Inter-row cultivation	38.00	ha
Insecticide application	32.50	ha
Karate Zeon	472.00	l
Kocide	15.00	kg
Harvesting		
Labour	11.00	hour
Post harvest		
Packaging	1.00	crate
Caulis Per Crate	16.00	curds

GROSS MARGIN CAULI

TOTAL GROWING COSTS	Rate		Total Cost $ ha
Preparation			
Plough	1		120.00
Rotary hoe	3		315.00
Level	1		40.00
Base dressing application	1		40.00
Superphosphate	3	t/ha	43.84
Potassium Sulphate	0.44	t/ha	305.51
Composting			
Compost & cartage	13	t/ha	562.50
Spreading	13	t/ha	250.00
Total Preparation			**1676.85**
Planting			
Cell transplants	174	trays	2088.00
Additional labour	3 people	12 hours	360.00
Total planting			2448.00
Crop Maintenance			
Herbicide application	1		32.5
Lasso	6	l/ha	90.00
Side dressing application	1		35.00
Nitrophoska 12.10.10	0.85	t/ha	503.10
Inter-row cultivation	2		76.00
Insecticide application	3		97.50
Karate Zeon	0.4	l/ha	188.80
Kocide	0.45	kg/ha	6.75
Total Crop Maintenance			1029.65
Harvesting			
Labour	0.157	hr/crate	993.03
Total Harvesting			**993.03**
Post harvest			
Packaging	575	crates	575
			575
TOTAL GROWING COSTS			**6722.53**
REVENUE			
Yield (curds per ha)			9200
Yield (crates per ha)			575
Yield (tonnes per ha)			23

Appendix 5. Sensitivity tables for sweetcorn crops

Compost		Yield t/ha				
Gross Margin	**504.57**	31.50	35.00	38.50	42.00	45.50
	170.00	(440.43)	154.57	749.57	1,344.57	1,939.57
Price paid	175.00	(282.93)	329.57	942.07	1,554.57	2,167.07
$/t	180.00	(125.43)	**504.57**	1,134.57	1,764.57	2,394.57
	185.00	32.07	679.57	1,327.07	1,974.57	2,622.07

Fertiliser		Yield t/ha				
Gross margin	**997.70**	31.50	35.00	38.50	42.00	45.50
	170.00	52.70	647.70	1,242.70	1,837.70	2,432.70
Price paid	175.00	210.20	822.70	1,435.20	2,047.70	2,660.20
$/t	180.00	367.70	**997.70**	1,627.70	2,257.70	2,887.70
	185.00	525.20	1,172.70	1,820.20	2,467.70	3,115.20

		Yield t/ha				
Spreading cost	**504.57**	31.50	35.00	38.50	42.00	45.50
	10	176.57	624.57	1,072.57	1,520.57	1,968.57
	15	116.57	564.57	1,012.57	1,460.57	1,908.57
Cost $/t	20	56.57	**504.57**	952.57	1,400.57	1,848.57
	25	(3.43)	444.57	892.57	1,340.57	1,788.57
	30	(63.43)	384.57	832.57	1,280.57	1,728.57

		Yield t/ha				
Cost of Compost	**504.57**	31.50	35.00	38.50	42.00	45.50
and Cartage	35	176.57	624.57	1,072.57	1,520.57	1,968.57
	45	56.57	**504.57**	952.57	1,400.57	1,848.57
Cost $/t	50	(3.43)	444.57	892.57	1,340.57	1,788.57
	55	(63.43)	384.57	832.57	1,280.57	1,728.57
	65	(183.43)	264.57	712.57	1,160.57	1,608.57

Appendix 6. Sensitivity tables for potato crops

Compost		Yield t/ha				
Gross Margin	**504.57**	31.50	35.00	38.50	42.00	45.50
	170.00	(440.43)	154.57	749.57	1,344.57	1,939.57
Price paid	175.00	(282.93)	329.57	942.07	1,554.57	2,167.07
$/t	180.00	(125.43)	**504.57**	1,134.57	1,764.57	2,394.57
	185.00	32.07	679.57	1,327.07	1,974.57	2,622.07

Fertiliser		Yield t/ha				
Gross margin	**997.70**	31.50	35.00	38.50	42.00	45.50
	170.00	52.70	647.70	1,242.70	1,837.70	2,432.70
Price paid	175.00	210.20	822.70	1,435.20	2,047.70	2,660.20
$/t	180.00	367.70	**997.70**	1,627.70	2,257.70	2,887.70
	185.00	525.20	1,172.70	1,820.20	2,467.70	3,115.20

		Yield t/ha				
Spreading cost	**504.57**	31.50	35.00	38.50	42.00	45.50
	10	176.57	624.57	1,072.57	1,520.57	1,968.57
	15	116.57	564.57	1,012.57	1,460.57	1,908.57
Cost $/t	20	56.57	**504.57**	952.57	1,400.57	1,848.57
	25	(3.43)	444.57	892.57	1,340.57	1,788.57
	30	(63.43)	384.57	832.57	1,280.57	1,728.57

		Yield t/ha				
Cost of Compost	**504.57**	31.50	35.00	38.50	42.00	45.50
and Cartage	35	176.57	624.57	1,072.57	1,520.57	1,968.57
	45	56.57	**504.57**	952.57	1,400.57	1,848.57
Cost $/t	50	(3.43)	444.57	892.57	1,340.57	1,788.57
	55	(63.43)	384.57	832.57	1,280.57	1,728.57
	65	(183.43)	264.57	712.57	1,160.57	1,608.57

Appendix 7. Sensitivity tables for cauliflower crops

Compost		Yield (curds/ha)				
Gross Margin	**2017.47**	8280	9200	10120	11040	11960
	0.75	(512.53)	177.47	867.47	1,557.47	2,247.47
Price paid	0.85	315.47	1,097.47	1,879.47	2,661.47	3,443.47
$/head	0.95	1,143.47	2,017.47	2,891.47	3,765.47	4,639.47
	1.05	1,971.47	2,937.47	3,903.47	4,869.47	5,835.47
	1.15	2,799.47	3,857.47	4,915.47	5,973.47	7,031.47

		Yield (curds/ha)				
Fertiliser	**2093.43**	8280	9200	10120	11040	11960
Gross Margin	0.75	(436.58)	253.42	943.42	1,633.43	2,323.43
	0.85	391.42	1,173.43	1,955.43	2,737.43	3,519.43
Price paid	0.95	1,219.43	2,093.43	2,967.43	3,841.43	4,715.43
$/head	1.05	2,047.43	3,013.43	3,979.43	4,945.43	5,911.43
	1.15	2,875.43	3,933.43	4,991.43	6,049.43	7,107.43

		Yield (curds/ha)				
Cost of compost	**2017.47**	8280	9200	10120	11040	11960
spreading	10	1,425.27	2,142.47	2,859.67	3,576.87	4,294.06
	15	1,362.77	2,079.97	2,797.17	3,514.37	4,231.56
Price	20	1,300.27	**2,017.47**	2,734.67	3,451.87	4,169.06
$/t	25	1,237.77	1,954.97	2,672.17	3,389.37	4,106.56
	30	1,175.27	1,892.47	2,609.67	3,326.87	4,044.06

		Yield (curds/ha)				
Cost of compost	**2017.47**	8280	9200	10120	11040	11960
	35	1,425.27	2,142.47	2,859.67	3,576.87	4,294.06
	45	1,300.27	**2,017.47**	2,734.67	3,451.87	4,169.06
	55	1,175.27	1,892.47	2,609.67	3,326.87	4,044.06
	65	1,050.27	1,767.47	2,484.67	3,201.87	3,919.06

16 curds to the crate

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