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COMPOSTING OF ONION AND OTHER VEGETABLE WASTES, WITH PARTICULAR REFERENCE TO CONTROL OF *ALLIUM* WHITE ROT

February 1999 – December 1999

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PRACTICAL SECTION FOR GROWERS

The loss of the best onion growing soils due to white rot infestation has forced onion production into areas with less suitable soils and climate for growing high quality onions. These disease-free areas are becoming more remote from established centralised packing and storage sites, increasing the need for road haulage with concomitant cost penalties and environmental pollution.

The accumulation of vegetable crop wastes in growing areas and processing centres poses a risk of potential infestation and contamination from crop pests and pathogens, as well as a source of odour and run-off pollution. Figures obtained from several major vegetable co-operatives and packers indicate that onions and root vegetables account for over 30,000 tonnes of waste annually in the UK, with landfill disposal costs of over £500K. Following the introduction of landfill taxes of £2-10 per tonne, these costs will rise further. One possible option for disposal of the waste is to return it to the field, since composted vegetable waste is a potential fertiliser and soil conditioner. In the case of onions, the waste may also provide a novel control solution for *Allium* white rot, since it contains compounds capable of inducing the sclerotia of the pathogen *Sclerotium cepivorum* to germinate, and germinated sclerotia are unable to survive in the absence of a living host. Application of composts which stimulate white rot sclerotia germination in infested soils would be an environmentally friendly method of disease control allowing the possibility of organic onion production in the future.

Composted vegetable wastes from production and processing centres can be disposed of on to fields. Although static or turned windrows can result in a significant reduction in the volume of the waste, they do not ensure that all pests and pathogens are killed, thus limiting the ease of disposal of the processed compost.

The aims of this project are to identify the optimum controlled composting regimes for primarily onion-based vegetable waste material to produce composts which:

- Are free of pests and pathogens
- Have white rot sclerotia stimulant activity
- Are partially stable, enabling storage for up to two months
- Have a soil conditioner/fertiliser value

The following summarises the results of year 1 of the project:

Two categories of onion waste, wet (peelings, whole onions) and dry (shale, tops) were identified. Composting each category of waste alone was either impractical, in terms of the bulk of material involved, or produced large volumes of run-off and unpleasant odours. A wet:dry onion waste mixture prepared to an 80% moisture content was found to be optimal in minimising run-off and odours produced during composting at 50 ºC for 7 days (Table 1). Mixtures of *Brassica* and carrot waste with onion shale prepared to the same moisture content and conditions of incubation gave similar results.

Table 1: Effect of onion waste composition on run-off and odour produced during composting at 50 ºC for 7 days

Dry Matter Content (%)	Comments
13	Odour very strong especially in the first few days Considerable run-off (50-100 ml)
16	No unpleasant odours 1-20 ml run-off
20	No unpleasant odours Very little run-off (*ca.* 1 ml)

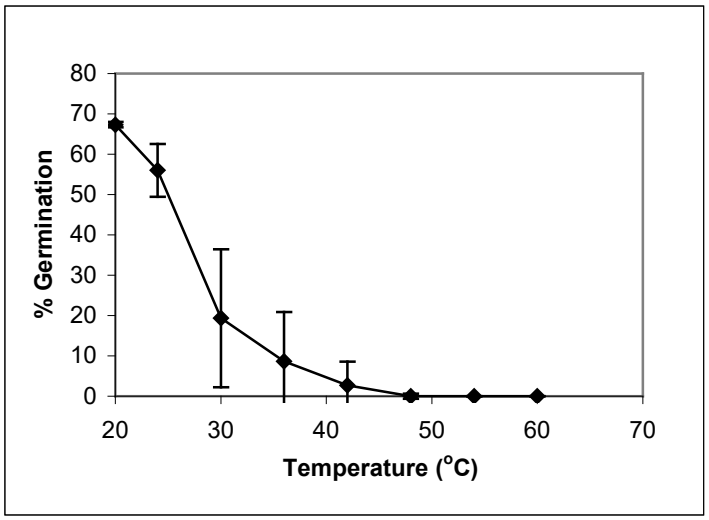
Composted onion peelings, *Brassica* and carrot waste each mixed with onion shale were found to contain nitrogen, phosphorus and potassium with measurable conductivities and thus have potential value as fertilisers (Table 2).

Table 2: Analysis of vegetable waste composted with onion shale for 7 days at 50 ºC. Values for nitrogen, phosphorus and potassium are based on fresh weight.

Sample	Total Nitrogen (%)	Phosphorus (ppm)	Potassium (%)	Conductivity (mS)
Onion peelings	0.574	823	0.65	0.68
Broccoli + cauliflower waste	0.792	941	1.40	1.13
Whole carrots	0.464	987	1.05	0.99

Sclerotia of *S. cepivorum* were incubated in flasks containing onion waste at a number of temperatures for 7 days. As the incubation temperature was increased, percentage germination of the sclerotia retrieved from the waste decreased (Figure 1). All sclerotia were destroyed at temperatures of 48 ºC and above.

Figure 1: Effect of temperature on germination (%) of sclerotia incubated in onion waste for 7 days. Values are the mean of 3 replicates.



Similar flask scale experiments were conducted at 50 ºC over 7 days with onion waste inoculated with propagules of the pathogens *Olpidium brassicae* and *Fusarium oxysporum*. These conditions destroyed all propagules of *O. brassicae* and reduced the viability of *F. oxysporum*.

Onion waste composted at two different temperatures (42 ºC and 54 ºC) for 3 and 7 days was analysed for the presence of the white rot sclerotia germination stimulant, di-n-propyl disulphide. The higher temperature and longer incubation period had no detrimental effect on the level of this compound in the onion waste compared to that found in the low temperature produced composts.

The effect of composted vegetable waste in sandy loam soil on the viability of sclerotia of *S. cepivorum* was found to be dependent on length of exposure and the amount of waste present. In general, the longer the sclerotia were in contact with the waste and the higher the rate of incorporation, the greater the reduction in viability.

Incorporation of composted onion, *Brassica* and carrot waste each mixed with onion shale into sandy loam soil at a rate of 1% and 10% (% by weight) had no effect on the germination of onion seed planted at time of incorporation and subsequent plant growth.

Practical and Financial Anticipated Benefits

- Return of onion growing land currently infested with white rot to onion production
- Less reliance on chemical treatments and reduction in length of crop rotations currently needed to avoid build-up of the white rot pathogen
- Reduction in transportation and landfill costs

MILESTONES

Year 1

Primary Milestones

1.1 Complete physical and chemical analysis of separated wastes supplied by Industrial partners.

1.2 Determine the temperature and aeration conditions and waste composition to achieve appropriate rates of degradation and control of odour and run-off pollutants during composting in the laboratory.

2.1 Determine the temperature and aeration conditions and waste composition to achieve elimination of white rot sclerotia and propagules of *Olpidium* and *Fusarium*, nematodes and onion fly larvae during composting in the laboratory.

3.1 Determine sclerotial germination activity in composts produced in 1.2 and 2.1 by monitoring volatiles using GC-MS/Electronic nose and by incorporating composts at various rates into soil containing sclerotia and monitoring survival after 3 months – short-term viability.

Secondary Milestones

1 Draw up detailed timetable of actions for each partner.

1.3 Obtain sources of wastes for flask scale experiments.

1.4 Determine fertiliser value (N, P, K, pH, conductivity) of bench-scale processed substrates.

4.1 Consortium to decide on cultivars for pot-based tests.

Year 2

Primary Milestones

3.2 Determine sclerotial germination activity of composts produced in 2.1 by monitoring volatiles using GC-MS/Electronic nose and by incorporating composts at various rates into soil containing sclerotia and monitoring survival for up to 12 months – long-term viability.

4.2 Assess optimised composts from 3.1 and 3.2 for effects on onion growth, white rot incidence and sclerotial survival in pot-based tests.

5.2 Produce composts in 20 tonne bulk composting tunnels at HRI-Wellesbourne for use in field trials and monitor survival of pathogens and pests.

6.2 Set up field trials to determine effect of early application and storage of compost before application on onion growth, white rot disease and sclerotial survival at HRI-Kirton and in commercial field sites.

Year 3

Primary Milestones

5.4 Produce composts in 20 tonne bulk composting tunnels at HRI-Wellesbourne for use in field trials and monitor survival of pathogens and pests during bulk tunnel composting.

6.4 Set up field trials to determine the effect of rates of application, storage and initial waste composition of compost produced in bulk composting tunnels in field experiments on onion growth, white rot disease and sclerotial survival in uninfested and white rot-infested soil (HRI-Kirton) and in commercial field sites. Monitor and harvest all field trials.

6.6 Preparation of industry-based manual on composting and utilisation of onion and other vegetable wastes.

Progress

The primary milestones 1.1, 1.2 and 3.1 have been completed. The primary milestone 2.1 has been partially completed. No work has to date been carried out involving the nematodes and onion fly larvae although these pests are expected to be destroyed by the composting conditions identified for elimination of the white rot pathogen, *S. cepivorum*. The future milestones look realistic.

SCIENCE SECTION

Introduction

The loss of the best onion growing soils due to white rot infestation has forced onion production into areas with less suitable soils and climate for growing high quality onions. These disease-free areas are becoming more remote from established centralised packing and storage sites, increasing the need for road haulage with concomitant cost penalties and environmental pollution.

The accumulation of vegetable crop wastes in growing areas and processing centres poses a risk of potential infestation and contamination from crop pests and pathogens, as well as a source of odour and run-off pollution. Figures obtained from several major vegetable co-operatives and packers indicate that onions and root vegetables account for over 30,000 tonnes of waste annually in the UK, with landfill disposal costs of over £500K. Following the introduction of landfill taxes of £2-10 per tonne, these costs will rise further. The option of disposal of vegetable wastes as animal feed is decreasing with a reduction in herds due to problems associated with BSE. One possible solution is for waste to be returned to the field, since composted vegetable waste is a potential fertiliser and soil conditioner. In the case of onions, the waste may also provide a novel control solution for *Allium* white rot, since it contains compounds capable of inducing the sclerotia of the pathogen *Sclerotium cepivorum* to germinate, and germinated sclerotia are unable to survive in the absence of a living host. Previous on-farm experiments (R. Oldershaw, pers. comm.) have indicated that windrow composted onion waste applied to fields may eliminate white rot sclerotia from infested soil. Application of composts which stimulate white rot sclerotia germination in infested soils would be an environmentally friendly method of disease control allowing the possibility of organic onion production in the future. There is consumer and retailer pressure to reduce the use of pesticides and less reliance would need to be placed on chemical treatments to control white rot.

Composted vegetable wastes from production and processing centres can be disposed of on to fields. Although static or turned windrows can result in a significant reduction in the volume of the waste, they do not ensure that all pests and pathogens are killed, thus limiting the ease of disposal of the processed compost. The uncontrolled nature of windrow composting means that while considerable odour and run-off pollutants are produced, useful compounds such as *S. cepivorum* sclerotia germination stimulants present in onion waste may be destroyed. In addition, the composting of a single waste may be less effective than blends of wastes, due to incorrect moisture content or carbon:nitrogen ratio.

This report details experiments undertaken to identify the optimum controlled composting regimes for onion and other vegetable wastes to produce composts which are free of pathogens and have white rot sclerotia stimulant activity.

Materials and Methods

Bench-scale Development and Assessment of a Controlled Composting System for Vegetable Wastes

Analysis of Separated Wastes Supplied by Industrial Partners

Vegetable waste collected from five of the industrial partners (Elgro Limited, Goldwood (Moulton) Limited, Fenmarc Produce Limited, G's Fresh Vegetables Limited and Bedfordshire Growers) at 3 different times of the year was analysed for total nitrogen, dry matter and ash content. These initial determinations provided the information required to calculate the moisture and nitrogen contents of the waste mixtures prepared for composting.

Composting of Vegetable Waste

Small-scale flask experiments were conducted using various mixtures of dry and wet onion waste prepared to different moisture contents to identify the optimum waste composition to achieve minimal run-off and control of odour. The onion waste mixtures (with 4 g urea/kg waste added to achieve a nitrogen content of 1.5% of dry matter) were composted in 2 litre "Quickfit" multiadapter flasks immersed in thermostatically controlled waterbaths. The waste mixtures (*ca.* 700 g) were placed on a perforated stainless steel platform within each flask and the flasks immersed in the waterbaths such that the water level was above the level of the enclosed waste. Each flask was connected to ancillary equipment providing independent aeration of the waste. The waste was aerated for 2 minutes in every 30 minutes at a flow rate of 250 ml/min by means of flow meters. The temperature of the waste in the flasks was monitored with Squirrel multipoint temperature loggers (Grant Instruments Limited, Cambridge, UK). Ammonia, carbon dioxide and oxygen levels in the flasks were monitored using a Draeger Gas Detector (Dragerwerk, Lubeck, Germany) with appropriate sample tubes (CH20501, CH31401, 8101991 and 6728081 respectively). The waste was incubated at 50 ^{o}C for 7 days after which any run-off was measured and weight loss, dry matter and ash contents determined as described previously [Noble & Gaze, 1994].

Similar experiments were conducted using *Brassica* and carrot waste prepared to an 80% moisture content (6 parts wet waste: 1 part dry waste by weight) which was found to be optimal for the onion waste with respect to minimising run-off. Onion shale served as the dry material for each of the *Brassica* and carrot waste mixtures. These wastes were chopped to *ca.* 3 cm pieces to fit in the flasks and encourage degradation.

To ascertain the potential fertiliser value of the various waste mixtures, their conductivity and pH was measured and a sample of composted onion, *Brassica* and carrot waste analysed for nitrogen (no urea added), phosphorus and potassium.

Elimination of Pathogens from Infected Vegetable Waste

The pathogens of interest in this study are *Sclerotium cepivorum*, *Olpidium brassicae* and *Fusarium oxysporum*. The source and maintenance of each of these pathogens is described below:

S. cepivorum **-** Sclerotia from two 14 day old Potato Dextrose Agar (PDA) plate cultures (Kirton strain) were removed using a sterile spatula and added to 10 ml sterile distilled water (SDW). The sclerotia suspension was homogenised for 30 seconds then added to 500 ml SDW. One hundred ml of this suspension was used to inoculate mushroom spawn bags (Van Leer Packaging Systems Limited) containing 1920 g sand (Dried Silica Sand, Hepworth Minerals and Chemicals), 80 g flaked maize (Pure Country) which had been ground in a blender (Waring) and 175 ml water, previously autoclaved at 15 psi for 15 min. The bags were heat sealed and incubated for 6 weeks at 20 ºC. Sclerotia were retrieved from the bags after this period by adding water and decanting off the sclerotia into a 212 µm mesh size sieve (Endecotts). The sclerotia were left to dry in a laminar flow cabinet then mixed to 50% with sand, enclosed within fine mesh bags (Lockertex) and buried outside in soil *ca*. 15 cm deep for 12 weeks to condition the sclerotia. After this period the sclerotia were retrieved as previously described. This provided a stock of conditioned sclerotia for future experiments.

O. brassicae – Resting spores of *O. brassicae* were provided by J. Walsh and J. Bambridge, HRI, Wellesbourne.

F. oxysporum – SDW was added to 5 day old plate cultures of *F. oxysporum* provided by J. Carder and C. Grant, HRI, Wellesbourne to suspend the microconidia. The microconidia were counted and 2 ml of a 10^6 conidial suspension added to 10 g of sterile talc in a 50 ml Duran bottle. The inoculated talc was incubated at room temperature (*ca*. 22 ºC) for 6 weeks during which time chlamydospores of *F. oxysporum* formed. This served as a stock of the organism.

Effect of Temperature and Aeration on the Survival of Pathogens

S. cepivorum

Conditioned sclerotia (100) enclosed within fine mesh bags containing 2 g of onion waste were placed in the centre of onion waste mixtures in flasks and incubated at various temperatures for up to 7 days. To investigate the effect of volatiles released from the composting onion waste on the viability of the sclerotia without subjecting them to the composting temperatures, similar bags of sclerotia were incubated in the flask nozzles. There were 3 replicate flasks per treatment each incubated in a separate waterbath. At intervals throughout the 7 day incubation, bags of sclerotia were removed from the composting flasks. Sclerotia were washed from the onion waste with water, collected on a 212 µm mesh size sieve, and retrieved using forceps under a binocular microscope. The sclerotia were surface sterilised in sodium hypochlorite (>5% but <16% available chlorine) for 1.5 minutes using a Gilson and modified 10 ml tip which held the sclerotia on a mesh platform [Williams, Whipps & Cooke, 1998]. The sclerotia were rinsed in SDW four times and plated on to PDA containing 18 mg

chlorotetracycline/l of agar. Viability of the sclerotia was assessed after 7 and 14 days.

On the basis of the information obtained using the onion waste, subsequent experiments involving *S. cepivorum* and composting the *Brassica* and carrot waste were conducted at 50 ºC over 7 days.

O. brassicae

One ml of water containing 3000 resting spores of *O. brassicae* was used to inoculate 30 g of autoclaved sharp sand (Silvaperl Sharp Sand, William Sinclair Horticulture Limited). The sand was allowed to air dry before enclosing it within a fine mesh bag. Mesh bags containing the inoculated sand were placed in the centre of onion waste mixtures in flasks and incubated for 7 days at 50 ºC. After 7 days incubation the sand containing the *O. brassicae* resting spores was retrieved and mixed with a further 30 g of sand. Seven day old lettuce seedlings (*Lactuca sativa* L., cultivar Little Gem) grown in vermiculite at 15 ºC were transplanted into P40 modules containing the sand, watered with NFT solution every second day, and monitored for 8 weeks for symptoms of *O. brassicae* infection. Controls consisted of inoculated sand incubated on the bench and uninoculated sand.

F. oxysporum

Talc (0.1 g) inoculated with *F. oxysporum* was mixed with 10 g of 2 mm sieved Wellesbourne soil, enclosed within fine mesh bags and incubated in onion waste in flasks for 7 days at 40 ºC and 50 ºC. After 7 days the inoculated soil was removed from the flasks and plated on to Komada medium selective for *F. oxysporum* (see Appendix for media preparation details).

Sclerotia Stimulant Activity of Composted Vegetable Wastes

To determine the effect of composting temperature on the sclerotial germination stimulant di-n-propyl disulphide (dpds), a mixture of onion shale and peelings prepared to an 80% moisture content was incubated at 42 ºC and 54 ºC for 3 and 7 days. A sample of each of the composts produced was analysed using Gas Chromatography – Mass Spectrometry (GC-MS). The remainder of the composts produced from this experiment were used to set up a pot bioassay. Various rates of the composts (1%, 10% and 50% by weight) were incorporated into sieved sandy loam soil (Bedfordshire) containing 20% vermiculite to prevent clumping of the soil. Seven cm square pots were filled with the soil-compost mixtures (220 g) and 3 mesh bags (2 cm x 2 cm) each containing 2 g of 50:50 sand:soil and 100 sclerotia buried in the pots. There were 3 replicate pots per treatment arranged in a randomised block design. The mesh bags were retrieved at one month intervals and the sclerotia assessed for their viability (% soft and % germination) as previously described.

A similar bioassay was set up with *Brassica* and carrot wastes composted with onion shale at 50 ºC for 7 days.

In both bioassays, onion seeds (*Allium cepa*, cultivar White Lisbon) were planted in pots containing the soil-vegetable waste mixtures to check for any phytotoxic effects of the raw and composted wastes.

Results

Bench-scale Development and Assessment of a Controlled Composting System for Vegetable Wastes

Analysis of Separated Wastes Supplied by Industrial Partners

The onion waste produced by the industrial partners varied but all produced dry onion waste (shale-skins or onion tops) with the majority also producing some type of wet waste (peelings or whole onions). The dry matter content of the wastes was above 70% for the dry wastes and below 16% for the wet wastes (Table 1). The dry wastes were found to have a higher ash content than the wet wastes but lower total nitrogen.

Table 1: Dry matter (DM), ash and total nitrogen (N) content of onion waste. Each value is the mean of two replicates.

Company	Waste	DM (%)	Ash (% of DM)	Total N (% of DM)
Elgro Ltd	(i) shale	79.5	10.8	0.68
	(ii) peelings	14.4	4.5	1.00
	(iii) whole onions	15.4	4.6	1.37
Goldwood (Moulton) Ltd	(i) shale	74.8	9.0	0.56
	(ii) peelings	12.4	5.3	1.25
Fenmarc Produce Ltd	(i) shale	75.6	6.8	0.40
	(ii) tops + shale	80.0	12.6	1.03
G's Fresh Vegetables Ltd	(i) shale	68.5	14.5	0.50
	(ii) whole onions	10.4	8.0	1.44
Bedfordshire Growers Ltd	(i) shale	72.5	14.9	0.44
	(ii) whole onions	10.7	5.7	1.63

The analysis of the *Brassica* and carrot waste produced by the industrial partners is shown in Table 2. In general, these wastes had a similar ash content to the wet onion waste but a lower dry matter content. In addition, the total nitrogen content of the *Brassica* waste was higher than that of the onion waste.

Table 2: Dry matter (DM), ash and total nitrogen (N) content of *Brassica* and carrot waste

Company	Waste	DM (%)	Ash (% of DM)	Total N (% of DM)
Elgro Ltd	Broccoli stalks	8.1	6.7	1.18
	White cabbage	7.6	5.7	2.20
Fenmarc	Broccoli + cauliflower	10.8	5.0	1.99
	Wet carrot waste	8.6	4.1	1.20
G's Fresh Vegetables Ltd	Whole florets of broccoli	8.9	8.1	4.75
	Whole carrots	10.9	3.4	0.92

Composting of Vegetable Waste

Composting wet onion waste alone (13% dry matter) was found to be unsuitable in terms of the volume of run-off and odour produced (Table 3). An onion waste mixture with a dry matter content of 20% (10:1 wet: dry waste by weight) was found to be the optimum in terms of minimising run-off. Under these conditions the waste was found to degrade well, softening and darkening. Waste compositions drier than 20% were considered impractical in terms of the bulk of the material involved. No straw was included in the composting mixtures as originally detailed in the project proposal as the dry onion waste with the aeration supplied were found to be adequate to keep the composting process aerobic. Typical CO_2 and O_2 levels measured in the flasks during composting of the waste are detailed in Table 4. Carbon dioxide levels were higher in the composting *Brassica* wastes than in the composting onion or carrot wastes. Oxygen concentration was lowest in the composting broccoli + cauliflower waste. No ammonia was detected. This was presumably due to the acidic nature of the waste mixtures (Table 7) causing any ammonia released to be converted to ammonium.

Table 3: Effect of onion waste composition on run-off and odour produced during composting at 50 ºC for 7 days

Dry Matter Content (%)	**Ratio of Wet:Dry Waste**	**Comments**
13	1:0	Odour very strong especially in the first few days Considerable run-off (50-100 ml)
16	16:1	No unpleasant odours 1-20 ml run-off
20	10:1	No unpleasant odours Very little run-off (*ca.* 1 ml)

Table 4: CO_2 and O_2 (%) levels detected in flasks of vegetable waste mixed with onion shale after 2 days composting at 50 ºC

Waste	**CO_2**	**O_2**
Onion peelings	1.5	19.5
Broccoli stalks	5.5	19.0
White cabbage	5.0	16.2
Broccoli + cauliflower	8.5	13.0
Wet carrot waste	2.5	20.1
Whole florets of broccoli	5.0	18.0
Whole carrots (chopped)	4.0	17.1

Similar to the onion waste, the *Brassica*- and carrot-onion shale mixtures prepared to an 80% moisture content produced little run-off (Table 5) or unpleasant odours when composted. Weight loss from the vegetable waste during composting ranged from 5.8-12.9%.

Table 5: Weight loss (%) and run-off (ml) from various vegetable wastes mixed with onion shale during composting at 50 °C for 7 days

Waste	Weight Loss (%)	Run-off (ml)
Onion peelings	10.0	0
Broccoli stalks	12.9	9
White cabbage	8.3	11
Broccoli + cauliflower waste	7.0	7
Wet carrot waste	5.8	1
Whole florets of broccoli	6.4	1
Whole carrots (chopped)	8.4	0

Table 6 details typical values for dry matter and ash content of the vegetable wastes before and after composting. Dry weight of the onion, carrot and broccoli floret waste mixtures was lower after composting because water produced from respiration exceeded moisture losses in composting. Due to loss of carbon, ash content was higher after composting than before.

Table 6: Dry weight and ash contents of vegetable wastes mixed with onion shale before and after composting for 7 days at 50 °C

Waste	Dry Weight of Compost Mixture (%)		Ash Content (%)	
	Before	After	Before	After
Onion peelings	22.1	19.3	7.2	13.9
Broccoli stalks	12.6	12.5	6.1	6.3
White cabbage	11.9	12.3	7.3	8.5
Broccoli + cauliflower waste	13.7	14.9	5.6	5.7
Wet carrot waste	22.5	20.7	5.0	5.3
Whole florets of broccoli	17.2	15.5	5.2	7.9
Whole carrots (chopped)	23.3	18.7	4.8	7.4

All the composted wastes were found to be acidic, with mixtures containing broccoli waste being least acidic (Table 7). Conductivities ranged from 0.68-1.88 mS. Nitrogen, phosphorus and potassium were present in the three categories of waste, onion, *Brassica* and carrot, although their quantities varied (Table 8). The onion waste was found to have the lowest amounts of phosphorus and potassium with the *Brassica* waste having the highest nitrogen and potassium content, and the carrot waste the lowest nitrogen and highest phosphorus.

Table 7: Conductivity (mS) and pH measurements of vegetable waste + onion shale composted for 7 days at 50 ºC. Values are the mean of two measurements.

Waste	Conductivity	pH
Onion peelings	0.68	3.82
Broccoli stalks	1.04	4.75
White cabbage	0.98	4.67
Broccoli + cauliflower waste	1.13	5.97
Wet carrot waste	1.10	3.65
Whole florets of broccoli	1.88	6.62
Whole carrots (chopped)	0.99	4.14

Table 8: Analysis of vegetable waste (no urea added) composted with onion shale for 7 days at 50 ºC. All values are based on fresh weight.

Sample	Total Nitrogen (%)	Ammonia Nitrogen (mg/l)	Phosphorus (ppm)	Potassium (%)
Onion peelings	0.574	128.5	823	0.65
Broccoli + cauliflower waste	0.792	237.4	941	1.40
Whole carrots	0.464	48.8	987	1.05

Elimination of Pathogens from Infected Vegetable Waste

Effect of Temperature and Aeration on the Survival of Pathogens

S. cepivorum

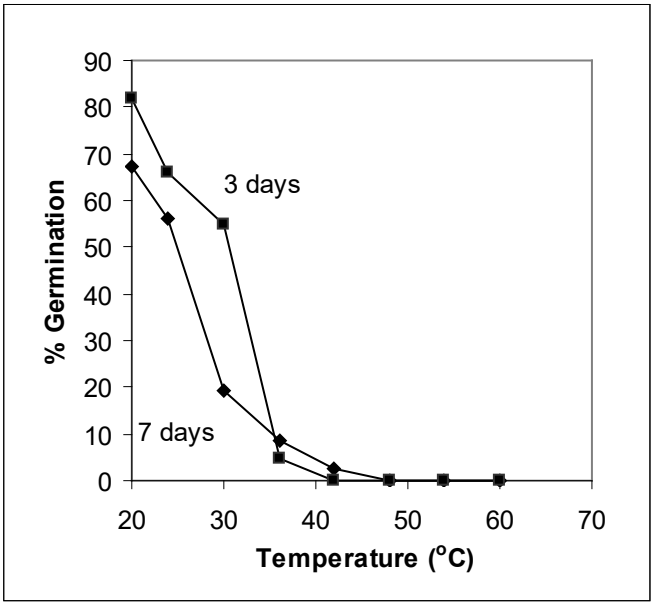
The results of preliminary experiments are detailed in Table 9. In most experiments a temperature of 40 ºC and above was found to destroy all sclerotia incubated in the onion waste in the flasks. In contrast, the viability of the sclerotia held in the nozzles of the flasks was not as greatly affected. Indeed, the sclerotia in the nozzles of the flasks held at 40 ºC and 55 ºC showed no reduction in viability compared to the controls. Interestingly, the sclerotia in the flask nozzles tended to be colonised by a large number of contaminants.

Table 9: Germination (%) of sclerotia held in onion waste in flasks and in the flask nozzles incubated for up to 7 days at a variety of temperatures. Values are the mean of 3 replicates ± 1 SE. Germination of control sclerotia = 96% to 100%.

Temperature	Incubation (Days)					
	3		5		7	
	Flask	Nozzle	Flask	Nozzle	Flask	Nozzle
40 ºC	0	98.7 ± 1.33	0	98.0 ± 1.15	0	98.0 ± 0
50 ºC	0	96.3 ± 0.33	2.0 ± 1.53	88.0 ± 6.66	1.0 ± 1.00	61.7 ± 11.21
55 ºC	0	92.0 ± 4.62	0	95.3 ± 2.40	0	92.7 ± 4.67
60 ºC	0	84.0 ± 6.93	0	76.7 ± 5.21	0	48.7 ± 12.35

Figure 1 shows the effect of increasing temperature on germination of *S. cepivorum*. As incubation temperature was increased percentage germination decreased with no germination after 3 and 7 days incubation at temperatures of 48 ºC and above. Incubation of sclerotia in each of the *Brassica* and carrot wastes with onion shale at 50 ºC for 7 days was also found to decrease percentage germination to zero.

Figure 1: Effect of temperature and incubation period (days) on germination (%) of sclerotia held in onion waste. Values are the mean of 3 replicates.



O. brassicae

Symptoms of the virus transmitted by *O. brassicae*, Lettuce Big Vein Virus (LBVV), were apparent on control plants inoculated with the pathogen and spores of the fungus were visible in the plant roots. No symptoms of LBVV were however present in the plants grown in sand inoculated with *O. brassicae* spores which had been incubated in onion waste at 50 ºC for 7 days.

F. oxysporum

Table 10 details the results of a preliminary experiment involving *F. oxysporum*. Temperatures of 40 ºC and 50 ºC were not sufficient to destroy all propagules although viability compared to the control was greatly reduced.

Table 10: *F. oxysporum* recovered after 7 days incubation at 40 ºC and 50 ºC in onion waste. Each value is the mean of two replicates.

Treatment	**Cfu/g soil**
Control	9.6×10^3
40 ºC	6.0×10^2
40 ºC	7.7×10^3
50 ºC	5.0×10^1
50 ºC	<100

Sclerotia Stimulant Activity of Composted Vegetable Wastes

The GC-MS analysis of the onion waste composted at 42 ºC and 54 ºC over 3 and 7 days is detailed in Table 11. The fresh onion waste was found to contain more di-n-propyl disulphide (dpds) than the composted wastes. In general however there was no difference in dpds content between the waste composted at 42 ºC and 54 ºC for 3 and 7 days. The results for the 3 day old 42 ºC composted waste are slightly confusing in that two samples were found to possess similar levels of dpds to the other composts but one sample possessed ten times this quantity. The composition of the latter with respect to the other volatiles present was found to be identical to the other replicates. A further replicate will be tested to check this result. No diallyl disulphide (DADS) was detected in the fresh or composted waste.

Table 11: GC-MS analysis of composted onion waste

Compound (mg/kg onion waste)	**3 days at 42 ºC**			**7 days at 42 ºC**			**Fresh Onion Shale**
	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	
di-n-propyl disulphide	0.02	0.01	0.13	0.01	0.01	0.01	0.05
Methyl mercaptan	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
n-propyl mercaptan	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Dimethyl disulphide	<0.10	<0.10	<0.10	0.02	<0.10	<0.10	<0.10
di-n-propyl sulphide	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10

Compound (mg/kg onion waste)	**3 days at 54 ºC**			**7 days at 54 ºC**			**Fresh Peelings**
	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	
di-n-propyl disulphide	<0.01	0.01	0.01	<0.01	0.02	0.01	0.05
Methyl mercaptan	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
n-propyl mercaptan	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Dimethyl disulphide	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
di-n-propyl sulphide	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10

Onion Waste Bioassay

Retrieval of sclerotia after 1 month - Table 12 details the percentage of soft sclerotia retrieved after one month buried in soil-compost mixtures. The 1% compost treatments had no significant effect on the number of soft sclerotia. However, the waste composted at 54 ºC for 3 and 7 days incorporated at 10% and 50% significantly increased the number of soft sclerotia retrieved. The 1% and 10% rate treatments had no significant effect on sclerotia germination (Table 13). The 7 day old 54 ºC compost was the only treatment at the 50% rate to reduce germination significantly compared to the controls.

Table 12
Soft sclerotia (%) of *S. cepivorum* retrieved after 1 month buried in pots of sandy loam soil containing 1%, 10% and 50% raw or composted onion waste. Values are the mean of three replicate bags each containing 100 sclerotia ± 1 SE. $p<0.05$.

Treatment	1% Waste	10% Waste	50% Waste
Control	14.7 ± 4.33	6.3 ± 0.88	10.7 ± 0.33
Raw[a]	8.0 ± 3.79	4.7 ± 2.33	8.0 ± 2.89
3 d at 42[b]	9.7 ± 0.33	4.7 ± 0.67	7.0 ± 1.53
7 d at 42[b]	10.0 ± 4.36	6.0 ± 2.00	3.0 ± 0.58
3 d at 54[c]	7.7 ± 0.88	12.0 ± 2.65	19.0 ± 1.73
7 d at 54[c]	9.0 ± 2.31	10.0 ± 3.00	17.3 ± 5.61
	LSD = 6.8	LSD = 3.4	LSD = 6.0

a uncomposted raw onion waste
b onion waste composted for 3 or 7 days at 42 ºC
c onion waste composted for 3 or 7 days at 54 ºC

Table 13
Germination (%) of sclerotia of *S. cepivorum* retrieved after 1 month buried in pots of sandy loam soil containing 1%, 10% and 50% raw or composted onion waste. Values are the mean of three replicate bags each containing 100 sclerotia ± 1 SE. $p<0.05$.

Treatment	1% Waste	10% Waste	50% Waste
Control	87.3 ± 2.40	86.0 ± 2.31	72.7 ± 8.82
Raw[a]	83.3 ± 2.91	84.7 ± 2.40	83.3 ± 8.67
3 d at 42[b]	84.7 ± 4.67	88.7 ± 7.33	38.7 ± 29.81
7 d at 42[b]	84.7 ± 4.06	92.0 ± 3.06	80.7 ± 4.06
3 d at 54[c]	88.0 ± 3.06	93.3 ± 1.76	31.3 ± 8.82
7 d at 54[c]	86.0 ± 5.03	86.0 ± 7.02	24.7 ± 14.25
	LSD = 8.3	LSD = 10.0	LSD = 43.2

Retrieval of sclerotia after 2 months – Table 14 details the soft sclerotia retrieved after 2 months burial in soil-compost mixtures. Similar to the results after 1 month, the 1% rate treatments had no significant effect on the number of soft sclerotia retrieved, and the 10% and 50% rates of the 7 day old 54 ºC compost increased the percentage of soft sclerotia significantly compared to the control. In addition, the 10% raw and 50% 3 day old 54 ºC treatments significantly increased the percentage of soft sclerotia.

The effect of the 1% and 10% waste rates on viability was minimal with only the 1% raw waste and 10% 7 day old 54 ºC compost treatments reducing germination significantly (Table 15). In contrast, all the composted waste treatments at the 50% rate reduced germination significantly compared to the controls.

Table 14
Soft sclerotia (%) of *S. cepivorum* retrieved after 2 months buried in pots of sandy loam soil containing 1%, 10% and 50% raw or composted onion waste. Values are the mean of three replicate bags each containing 100 sclerotia ± 1 SE. $p<0.05$.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	14.0 ± 1.53	12.3 ± 2.19	11.3 ± 6.17
Raw[a]	12.0 ± 1.53	17.7 ± 2.3	5.0 ± 2.08
3 d at 42[b]	14.7 ± 0.67	12.3 ± 0.67	12.0 ± 1.73
7 d at 42[b]	9.3 ± 2.91	8.7 ± 2.67	8.0 ± 4.58
3 d at 54[c]	14.7 ± 2.67	10.7 ± 1.20	37.0 ± 9.87
7 d at 54[c]	19.7 ± 2.33	20.3 ± 1.76	34.7 ± 8.01
	LSD = 13.2	LSD = 5.3	LSD = 13.4

a uncomposted raw onion waste
b onion waste composted for 3 or 7 days at 42 ºC
c onion waste composted for 3 or 7 days at 54 ºC

Table 15
Germination (%) of sclerotia of *S. cepivorum* retrieved after 2 months buried in pots of sandy loam soil containing 1%, 10% and 50% raw or composted onion waste. Values are the mean of three replicate bags each containing 100 sclerotia ± 1 SE. $p<0.05$.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	97.0 ± 0	96.7 ± 2.03	96.7 ± 3.33
Raw[a]	90.0 ± 4.04	94.7 ± 2.33	81.0 ± 9.17
3 d at 42[b]	99.0 ± 1.00	97.7 ± 2.33	43.0 ± 25.17
7 d at 42[b]	95.7 ± 2.96	100 ± 0	64.3 ± 14.89
3 d at 54[c]	95.7 ± 1.33	93.3 ± 2.03	39.0 ± 24.03
7 d at 54[c]	95.7 ± 2.96	80.0 ± 5.13	29.0 ± 18.15
	LSD = 5.4	LSD = 6.6	LSD = 30.5

Retrieval of sclerotia after 3 months – The results for the soft sclerotia retrieved after 3 months burial are detailed in Table 16. Every treatment at the 10% rate significantly increased the percentage of soft sclerotia retrieved. In contrast, no increase in soft sclerotia was recorded with any of the treatments at the 1% and 50% rates. This may relate to the low level of soft sclerotia in the control treatment at the 10% rate.

Similar to the results after 2 months, the 10% 7 day old 54 ºC compost treatment and all the composted waste treatments at the 50% rate reduced germination of retrieved sclerotia significantly compared to the controls (Table 17).

Table 16
Soft sclerotia (%) of *S. cepivorum* retrieved after 3 months buried in pots of sandy loam soil containing 1%, 10% and 50% raw or composted onion waste. Values are the mean of three replicate bags each containing 100 sclerotia ± 1 SE. $p<0.05$.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	22.3 ± 4.06	10.0 ± 1.00	20.0 ± 2.00
Raw[a]	15.3 ± 3.33	22.7 ± 4.06	21.3 ± 3.84
3 d at 42[b]	18.7 ± 3.84	21.0 ± 4.58	11.3 ± 0.88
7 d at 42[b]	14.0 ± 0	20.7 ± 6.64	9.7 ± 3.84
3 d at 54[c]	21.0 ± 7.51	24.0 ± 5.51	25.3 ± 5.04
7 d at 54[c]	19.0 ± 7.77	32.0 ± 4.36	27.0 ± 5.69
	LSD = 11.2	LSD = 3.1	LSD = 8.5

a uncomposted raw onion waste
b onion waste composted for 3 or 7 days at 42 ºC
c onion waste composted for 3 or 7 days at 54 ºC

Table 17
Germination (%) of sclerotia of *S. cepivorum* retrieved after 3 months buried in pots of sandy loam soil containing 1%, 10% and 50% raw or composted onion waste. Values are the mean of three replicate bags each containing 100 sclerotia ± 1 SE. $p<0.05$.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	98.0 ± 1.00	96.7 ± 2.03	96.7 ± 2.03
Raw[a]	94.3 ± 1.33	94.3 ± 2.96	85.7 ± 9.77
3 d at 42[b]	96.7 ± 2.03	93.3 ± 3.76	60.0 ± 25.42
7 d at 42[b]	99.0 ± 1.00	94.7 ± 3.93	36.7 ± 15.94
3 d at 54[c]	96.3 ± 3.67	93.3 ± 2.03	22.3 ± 7.42
7 d at 54[c]	91.3 ± 5.67	86.0 ± 2.08	35.7 ± 22.26
	LSD = 6.5	LSD = 6.3	LSD = 35.0

Test for phytotoxicity - The presence of 1% and 10% raw or composted onion waste in the sandy loam soil had no significant detrimental effect on germination of onion seeds planted at the time of waste incorporation (Table 18). In addition, no subsequent symptoms of phytotoxicity in the established seedlings were observed.

Table 18
Number of 8 week old healthy plants growing in pots of sandy loam soil amended with 1% and 10% raw or composted onion waste. Five onion seeds (White Lisbon) were planted in each pot at the time of incorporation of the waste. Values are the mean of 3 replicate pots ± 1 SE. $p<0.05$.

Treatment	**1% Waste**	**10% Waste**
Control	3.3 ± 0.88	2.0 ± 0.58
Raw[a]	3. 0 ± 0.58	3.7 ± 0.88
3 d at 42[b]	2.7 ± 0.33	2.3 ± 0.33
7 d at 42[b]	3.3 ± 0.33	2.0 ± 0.58
3 d at 54[c]	2.3 ± 0.33	2.3 ± 0.88
7 d at 54[c]	4.3 ± 0.33	4.7 ± 1.86
	LSD = 1.1	LSD = 2.1

a uncomposted raw onion waste
b onion waste composted for 3 or 7 days at 42 °C
c onion waste composted for 3 or 7 days at 54 °C

Brassica Waste, Carrot Waste + Onion Shale Bioassay

Retrieval of sclerotia after 1 month - Table 19 details the percentage of soft sclerotia retrieved after 1 month buried in soil-compost mixtures. The effect of the vegetable wastes on the sclerotia increased as the rate of incorporation was increased, although the effect of particular waste types followed no clear trend. The 1% rate of both the raw and composted waste had no effect on the number of soft sclerotia. The 10% rate of the composted carrot wastes and the 50% rates of the raw wet carrot waste and composted white cabbage and wet carrot wastes increased the percentage of soft sclerotia significantly compared to the controls.

Few treatments reduced germination of retrieved sclerotia significantly compared to the controls (Table 20). The effective treatments generally showed no clear trend with respect to waste type and rate of incorporation (1% raw broccoli stalks, 1% raw white cabbage, 50% raw wet carrot waste, 50% composted whole carrots) except the composted wet carrot waste which had a significant effect at all 3 rates.

Table 19

Soft sclerotia (%) of *S. cepivorum* retrieved after 1 month buried in pots of sandy loam soil containing different rates of raw or composted onion shale + other vegetable waste. Values are the mean of three replicate bags each containing 100 sclerotia ± 1 SE. $p<0.05$.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	3.7 ± 1.20	2.0 ± 1.00	3.3 ± 1.45
Raw BS	1.3 ± 0.88	5.0 ± 0.58	2.3 ± 1.33
Raw WCAB	4.3 ± 1.20	3.7 ± 3.67	3.3 ± 1.67
Raw BC	6.3 ± 1.86	3.0 ± 1.00	2.0 ± 1.53
Raw WCW	3.7 ± 0.33	3.0 ± 0.58	13.0 ± 8.00
Raw WB	4.0 ± 2.08	5.3 ± 1.86	1.0 ± 0.58
Raw WCAR	6.0 ± 3.00	5.3 ± 3.18	3.0 ± 1.15
	LSD = 3.4	**LSD = 4.1**	**LSD = 6.5**
Control	4.3 ± 1.67	2.3 ± 0.88	3.3 ± 3.33
7d 50 BS	5.7 ± 2.03	5.7 ± 2.03	6.7 ± 1.45
7 d 50 WCAB	5.0 ± 3.21	4.0 ± 1.73	9.7 ± 2.40
7 d 50 BC	7.3 ± 4.06	5.0 ± 1.15	4.7 ± 0.33
7 d 50 WCW	4.3 ± 0.88	7.3 ± 1.86	19.7 ± 6.36
7 d 50 WB	3.7 ± 0.67	3.3 ± 1.86	3.7 ± 1.33
1 7 d 50 WCAR	2.3 ± 1.86	7.3 ± 2.03	7.7 ± 1.45
	LSD = 4.6	**LSD = 3.7**	**LSD = 6.0**

Control = no added waste
Raw = raw waste
7 d 50 = waste composted for 7 days at 50 ºC
BS = Broccoli Stalks
WCAB = White Cabbage
BC = Broccoli + Cauliflower waste
WCW = Wet Carrot Waste
WB = Whole florets of Broccoli
WCAR = Whole Carrots

Table 20

Germination (%) of sclerotia of *S. cepivorum* retrieved after 1 month buried in pots of sandy loam soil containing different rates of raw or composted onion shale + other vegetable waste. Values are the mean of three replicate bags each containing 100 sclerotia ± 1 SE. $p<0.05$.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	99.0 ± 1.00	99.0 ± 1.00	91.0 ± 9.00
Raw BS	88.7 ± 5.67	95.7 ± 4.33	93.3 ± 2.03
Raw WCAB	91.3 ± 7.22	98.0 ± 1.00	100.0 ± 0
Raw BC	94.3 ± 2.96	100.0 ± 0	98.0 ± 1.00
Raw WCW	100.0 ± 0	98.0 ± 1.00	76.3 ± 9.13
Raw WB	96.7 ± 2.03	96.7 ± 2.03	92.0 ± 4.93
Raw WCAR	99.0 ± 1.00	97.7 ± 2.33	98.0 ± 1.00
	LSD = 7.5	**LSD = 4.2**	**LSD = 10.5**
Control	99.0 ± 1.00	98.0 ± 1.00	100.0 ± 0
7 d 50 BS	99.0 ± 1.00	96.7 ± 3.33	84.3 ± 2.96
7 d 50 WCAB	99.0 ± 1.00	99.0 ± 1.00	84.7 ± 3.93
7 d 50 BC	94.7 ± 2.33	95.7 ± 4.33	85.3 ± 3.93
7 d 50 WCW	92.3 ± 6.23	91.0 ± 1.00	70.3 ± 14.53
7 d 50 WB	95.7 ± 2.96	97.7 ± 2.33	82.0 ± 6.66
7 d 50 WCAR	100.0 ± 0	96.7 ± 2.03	59.3 ± 29.91
	LSD = 5.6	**LSD = 4.9**	**LSD = 25.8**

Control = no added waste
Raw = raw waste
7 d 50 = waste composted for 7 days at 50 ºC
BS = Broccoli Stalks
WCAB = White Cabbage
BC = Broccoli + Cauliflower waste
WCW = Wet Carrot Waste
WB = Whole florets of Broccoli
WCAR = Whole Carrots

Retrieval of sclerotia after 2 months – The results for the soft sclerotia retrieved after 2 months buried in soil-vegetable waste mixtures are detailed in Table 21. The 50% rate of incorporation had the biggest effect on the number of soft sclerotia retrieved, with 6 treatments (raw broccoli + cauliflower, raw wet carrot waste, composted white cabbage, composted wet carrot waste, composted whole florets of broccoli and composted whole carrots) increasing the percentage significantly compared to the controls. Three of these treatments (composted white cabbage, wet carrot waste and whole carrots) also had a significant effect at the 10% rate.

Table 21
Soft sclerotia (%) of *S. cepivorum* retrieved after 2 months buried in pots of sandy loam soil containing different rates of raw or composted onion shale + other vegetable waste. Values are the mean of three replicate bags each containing 100 sclerotia ± 1 SE. $p<0.05$.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	4.7 ± 0.88	3.0 ± 0.58	3.0 ± 1.15
Raw BS	6.3 ± 1.86	13.7 ± 2.03	5.0 ± 2.65
Raw WCAB	7.0 ± 2.52	5.0 ± 1.15	3.7 ± 1.86
Raw BC	5.7 ± 1.86	5.3 ± 0.88	10.0 ± 1.53
Raw WCW	4.3 ± 2.33	13.0 ± 3.06	11.7 ± 3.48
Raw WB	8.7 ± 2.33	11.0 ± 4.73	6.0 ± 0.58
Raw WCAR	3.3 ± 0.33	12.0 ± 1.73	6.3 ± 4.37
	LSD = 3.7	**LSD = 12.2**	**LSD = 5.1**
Control	3.7 ± 1.76	2.3 ± 0.33	2.3 ± 0.33
7 d 50 BS	7.0 ± 2.08	4.7 ± 1.20	9.7 ± 0.88
7 d 50 WCAB	9.7 ± 1.33	8.3 ± 0.88	32.0 ± 6.03
7 d 50 BC	16.0 ± 5.77	6.7 ± 1.20	7.7 ± 2.40
7 d 50 WCW	9.7 ± 3.7	14.0 ± 3.51	17.7 ± 6.74
7 d 50 WB	2.7 ± 0.33	5.7 ± 1.20	14.0 ± 7.94
7 d 50 WCAR	4.7 ± 2.40	17.7 ± 6.36	22.3 ± 3.33
	LSD = 10.6	**LSD = 4.9**	**LSD = 9.5**

Control = no added waste
Raw = raw waste
7 d 50 = waste composted for 7 days at 50 ºC
BS = Broccoli Stalks
WCAB = White Cabbage
BC = Broccoli + Cauliflower waste
WCW = Wet Carrot Waste
WB = Whole florets of Broccoli
WCAR = Whole Carrots

The effect of the 1% and 10% rate treatments on germination was minimal with only the 1% composted white cabbage and 10% raw broccoli stalks treatments reducing germination significantly compared to the control (Table 22). In contrast, all the composted waste treatments at the 50% rate, with the exception of the broccoli stalks, and the 50% rate of the raw wet carrot waste treatment significantly reduced germination.

Table 22
Germination (%) of sclerotia of *S. cepivorum* retrieved after 2 months buried in pots of sandy loam soil containing different rates of raw or composted onion shale + other vegetable waste. Values are the mean of three replicate bags each containing 100 sclerotia ± 1 SE. $p<0.05$.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	99.0 ± 1.00	100.0 ± 0	100 ± 0
Raw BS	99.0 ± 1.00	94.3 ± 2.96	98.0 ± 1.00
Raw WCAB	98.0 ± 1.00	99.0 ± 1.00	98.0 ± 1.00
Raw BC	100.0 ± 0	97.7 ± 2.33	98.0 ± 1.00
Raw WCW	99.0 ± 1.00	95.7 ± 4.33	84.7 ± 7.88
Raw WB	100.0 ± 0	99.0 ± 1.00	93.7 ± 3.33
Raw WCAR	100.0 ± 0	100.0 ± 0	93.7 ± 3.33
	LSD = 1.5	**LSD = 4.4**	**LSD = 7.0**
Control	99.0 ± 1.00	99.0 ± 1.00	99.0 ± 1.00
7 d 50 BS	100.0 ± 0	97.7 ± 2.33	81.0 ± 10.54
7 d 50 WCAB	93.3 ± 5.24	95.3 ± 2.33	57.3 ± 10.74
7 d 50 BC	100.0 ± 0	99.0 ± 1.00	55.7 ± 9.77
7 d 50 WCW	99.0 ± 1.00	98.0 ± 1.00	65.3 ± 11.78
7 d 50 WB	99.0 ± 1.00	96.7 ± 2.03	72.3 ± 16.19
7 d 50 WCAR	100.0 ± 0	96.7 ± 3.33	46.7 ± 21.70
	LSD = 4.1	**LSD = 4.0**	**LSD = 25.9**

Control = no added waste
Raw = raw waste
7 d 50 = waste composted for 7 days at 50 ºC
BS = Broccoli Stalks
WCAB = White Cabbage
BC = Broccoli + Cauliflower waste
WCW = Wet Carrot Waste
WB = Whole florets of Broccoli
WCAR = Whole Carrots

Test for phytotoxicity - Similar to the results of the onion waste bioassay, the presence of 1% and 10% raw or composted carrot and *Brassica* waste had no significant effect on the germination of onion seeds planted at the time of compost incorporation (Table 23) or any visible phytotoxic effects.

Table 23

Number of 8 week old healthy plants growing in pots of sandy loam soil amended with 1% and 10% raw or composted onion shale + other vegetable waste. Five onion seeds (White Lisbon) were planted in each pot at the time of incorporation of the waste. Values are the mean of 3 replicate pots ± 1 SE. $p<0.05$.

Treatment	**1% Waste**	**10% Waste**
Control	4.7 ± 0.88	6.0 ± 1.00
BS raw	5.0 ± 0	8.3 ± 1.33
WCAB raw	6.7 ± 3.48	6.7 ± 1.86
BC raw	6.7 ±1.86	6.3 ± 1.86
WCW raw	3.0 ± 1.00	13.0 ± 2.08
WB raw	4.3 ± 2.96	5.0 ± 1.73
WCAR raw	4.3 ±0.88	6.3 ± 1.45
	LSD = 3.9	**LSD = 3.3**
Control	3.7 ± 2.40	4.7 ± 0.33
BS 7 d 50	6.3 ± 2.40	5.3 ± 2.40
WCAB 7 d 50	7.3 ± 3.53	5.0 ± 1.53
BC 7 d 50	7.0 ± 2.52	5.3 ± 1.20
WCW 7 d 50	5.7 ± 2.40	6.0 ± 3.21
WB 7 d 50	3.3 ± 0.88	8.0 ± 2.52
WCAR 7 d 50	6.0 ± 4.51	3.7 ± 1.20
	LSD = 5.4	**LSD = 3.9**

Control = no added waste
Raw = raw waste
7 d 50 = waste composted for 7 days at 50 ºC
BS = Broccoli Stalks
WCAB = White Cabbage
BC = Broccoli + Cauliflower waste
WCW = Wet Carrot Waste
WB = Whole florets of Broccoli
WCAR = Whole Carrots

Discussion

The moisture contents of the wet onion, *Brassica* and carrot wastes were 90% or higher and hence composting these materials as individual wastes was impractical due to the run-off which would have been produced. Onion shale is readily available from pack houses and therefore was the ideal material to mix with the other wastes to decrease the moisture content. A temperature of 50 ^{o}C for a period of 7 days was initially chosen to compost the waste mixtures as this temperature is optimum for degradation of composting materials. Waste prepared to an 80% moisture content and composted under these conditions was soft and wet in texture, although the vegetable wastes could still be recognised, and produced little run-off and unpleasant odours during composting. These composting conditions had an effect on the three pathogens of interest when held in the waste, destroying sclerotia of *S. cepivorum* and resting spores of *O. brassicae* and reducing the viability of propagules of *F. oxysporum*.

There was no clear trend on the effect of holding sclerotia in the nozzles of flasks incubated at different temperatures except the presence of a large number of contaminants (Table 9). The sclerotia had been surface sterilised prior to plating on to growth medium and therefore the contaminants must have come from within the sclerotia. These were not present in the control sclerotia suggesting the volatiles released from the composting onion waste had weakened the test sclerotia allowing colonisation by other fungi. These fungi may be potential biocontrol agents and could be used in future studies.

The GC-MS analysis of the onion waste samples revealed composting reduces the di-propyl disulphide (dpds) content compared to fresh waste (Table 11). There was however no great difference in the composition of the volatiles analysed between the composts produced at the two temperatures and incubation periods. Interestingly, when these composts were used in the sclerotial burial bioassay pot test the composted onion waste treatments were generally more effective in reducing viability of the sclerotia than the fresh raw waste treatments. The higher temperature compost was the most effective treatment in reducing viability at the three rates of incorporation. The reason for this difference is unclear and may be the result of an increased level of degradation of the waste at the higher temperature leading to breakdown and release of other compounds not analysed.

Similar to the results of the onion bioassay, the composted *Brassica* and carrot waste treatments were more effective in reducing germination than the fresh raw waste, with the carrot-onion shale mixtures generally more effective than the *Brassica*. The effect of the three waste types on the viability of sclerotia was found to be dependent on the length of exposure and the amount of waste present. In general, the longer the sclerotia were in contact with the waste and the higher the rate of waste incorporation, the greater the reduction in viability.

In addition to the white rot stimulant aspect of the onion waste, the onion, *Brassica* and carrot waste composted mixtures have potential value as fertilisers in that all contain nitrogen, phosphorus and potassium (Table 8). No experiments have as yet examined the effects on plant growth, although the materials did not cause phytotoxicity to onion seedlings when incorporated at 1% and 10% into soil.

Conclusions

1. Onion wastes fall into two categories: wet (peelings, whole onions) with moisture content above 70% and dry (shale, tops) with moisture content below 16%.

2. Composting each category of waste alone was either impractical, in terms of the bulk of material involved, or produced large volumes of run-off and unpleasant odours. A wet:dry onion waste mixture prepared to an 80% moisture content was found to be optimal in minimising run-off and odours produced during composting at 50 ºC for 7 days.

3. *Brassica* (broccoli, white cabbage and cauliflower) and carrot wastes had moisture contents of 90% or higher. Mixtures of the *Brassica* and carrot waste with onion shale prepared to the same moisture content (80%) and conditions of incubation gave similar results to the wet: dry onion waste mixture.

4. The composted onion, *Brassica* and carrot waste mixtures prepared were shown to contain nitrogen, phosphorus and potassium with measurable conductivities and thus have potential value as fertilisers.

5. Temperatures of 48 ºC and above, held for 7 days in composting vegetable waste, destroys sclerotia of *S. cepivorum*.

6. Composting onion waste containing resting spores of *O. brassicae* and chlamydospores of *F. oxysporum* for 7 days at 50 ºC destroys all propagules of *O. brassicae* and reduces the viability of *F. oxysporum*.

7. Composting onion waste reduces the content of the white rot sclerotia germination stimulant, di-n-propyl disulphide (dpds) compared to fresh waste. Composting at a high temperature (54 ºC) however has no greater a detrimental effect on dpds content than composting at a lower temperature (42 ºC).

8. The effect of composted vegetable waste (onion, *Brassica* and carrot) in sandy loam soil on the viability of sclerotia of *S. cepivorum* is dependent on length of exposure and the amount of waste present. In general, the longer the sclerotia are in contact with the waste and the higher the rate of incorporation, the greater the reduction in viability.

9. Incorporation of the raw and composted onion, *Brassica* and carrot waste mixtures prepared in this study into sandy loam soil at a rate of 1% and 10% has no effect on the germination of onion seed planted at time of incorporation and did not cause phytotoxicity symptoms.

References

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Appendix

Komada selective medium for *Fusarium oxysporum*

Basal medium	
Dipotassium hydrogen phosphate K_2HPO_4	1.0 g
Potassium chloride KCl	0.5 g
Magnesium sulphate $MgSO_4$	0.5 g
Ethylenediaminetetra-acetic acid ferric-sodium salt	0.01 g
L-Asparagine	2.0 g
D-Galactose	20.0 g
Distilled water	960 ml

Adjust to pH 3.8 with *ca*. 0.75 ml 10% v/v phosphoric acid. Then add:

Agar	15 g

Sterilise basal medium. When cool add 40 ml sterile water containing:

Pentachloronitrobenzene	0.75 g
Bile, bovine (ox gall)	0.5 g
Disodium tetraborate $Na_2B_4O_7.10H_2O$	1.0 g
Streptomycin sulphate	0.3 g

Adjust to pH 3.8 with *ca*. 3.8 ml 10% v/v phosphoric acid.