Project Title:	Composting of onion and other vegetable wastes, with particular reference to control of *Allium* white rot.
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Key workers:	R. Noble and E. Coventry, HRI - composting and assessment of composts for white rot control.
Location of project:	HRI, Wellesbourne and Grower sites.
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Key words:	*Allium*, compost, vegetables, white rot, *Sclerotium cepivorum*

CONTENTS

PRACTICAL SECTION FOR GROWERS

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 years 1 and 2 of the project:

Two categories of onion waste, wet (peelings, crushed 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, and spring onion waste with straw, 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)

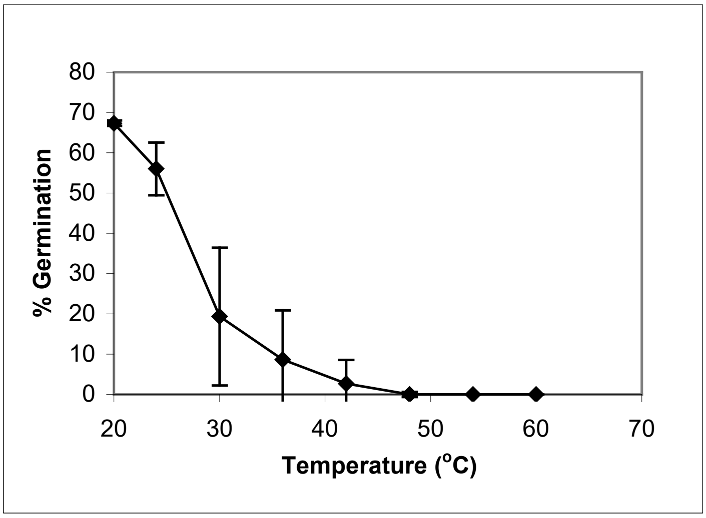
Composted onion peelings, *Brassica* and carrot waste each mixed with onion shale were found to contain nitrogen, phosphorus and potassium with measurable conductivities and thus have potential value as fertilisers (Table 2).

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*. The nematode, *Steinernema feltiae* and 5 day old onion fly larvae were also destroyed by these conditions.

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 with that found in the low temperature produced composts.

The effect of composted vegetable waste in sandy loam and silt soils on the viability of sclerotia of *S. cepivorum* in pot tests 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. The composted vegetable waste was also shown to influence the viability of sclerotia in peat soil although there was no relationship with rate of incorporation or duration of exposure.

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.

Composted onion waste incorporated into peat soil at a rate of 50% gave good control of *Allium* white rot in pots. The effect of this waste incorporation on disease control in silt and sandy loam soils is inconclusive at the moment due to the low levels of disease recorded in control treatments. These experiments will be repeated to try to improve the uniformity of disease in the different soil types.

Various mixtures of vegetable wastes (onion peelings + shale; sweetcorn + broccoli + onion shale; salad onion + straw), prepared to an 80% moisture content (85% = salad onion mixture) were composted for 7 days at 50 ºC in 6 or 20 tonne bulk capacity tunnels. No unpleasant odours and limited run-off were produced during composting. In addition, the volume of the waste mixtures generally halved during the composting period.

Bulk tunnel batches of composted salad onion waste (for a commercial field trial in Kent) and composted wet/dry onion waste (for a field trial at Kirton and commercial field trials in Lincolnshire, Cambridgeshire and Bedfordshire) were prepared. Results of this work will be reported in Year 3 of the project.

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.

Secondary Milestone

6.5 Consortium to agree on a draft outline of the industry-based manual.

Progress

All the primary and secondary milestones in Year 1 were completed. The primary milestones 4.2 and 5.2 have been completed and field trials at HRI-Kirton and four commercial field sites are underway (milestone 6.2). The primary milestone 3.2 has been partially completed. Pot experiments to determine the effect of compost incorporation on the long term viability (12 months) of sclerotia in sandy loam and peat soils have been set up and are nearing completion. 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:
1. identify the optimum controlled composting regime for salad onion waste.
2. identify the conditions necessary to destroy pest organisms in vegetable waste.
3. determine the effect of composted vegetable wastes on the short and long term viability of sclerotia of *S. cepivorum* in 3 soil types.
4. determine the effect of composted vegetable waste on onion growth and white rot incidence in pot-based tests.

Details of vegetable waste mixtures composted in bulk tunnels for use in field trials are also outlined.

Materials and Methods

Bench-scale Development and Assessment of a Controlled Composting System for Vegetable Wastes (Milestone 1.2)

A bench-scale system using 2 litre "Quickfit" multiadapter flasks and thermostatically controlled waterbaths was developed in Year 1 for composting the bulb onion waste supplied by five of the industrial partners. The same system was used to compost salad onion waste.

Analysis of Salad Onion Waste Supplied by Industrial Partner

Salad onion waste produced by one of the industrial partners (JJ Barker Limited) was analysed for dry matter content, as described in the Annual Report (Year 1), to calculate the moisture contents of mixtures prepared for composting.

Composting of Salad Onion Waste

Small scale flask experiments, as described in the Annual Report (Year 1), were conducted using mixtures of salad onion waste and straw prepared to various moisture contents (80%, 85% and 90%). The waste was incubated at 50 ºC for 7 days and any run-off recorded.

Elimination of Pests from Infested Waste (Milestone 2.1)

Similar flask scale experiments to those involving the pathogens in Year 1 of the project were undertaken with onion fly larvae and nematodes. Five day old onion fly larvae, enclosed within mesh bags containing onion waste, were placed in the centre of onion waste mixtures in flasks and incubated for 7 days at 50 ºC. The nematode, *Steinernema feltiae* was similarly added to flasks and subjected to the same conditions.

Sclerotia Stimulant Activity of Composted Vegetable Wastes (Milestone 3.2)

Various rates (1%, 10% and 50% by weight) of raw and composted vegetable waste were incorporated into sieved sandy loam soil (Bedfordshire) containing 20% vermiculite. Pots (7 cm x 7 cm x 8 cm) were filled with the soil-vegetable waste mixtures (220 g) and 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 1 month intervals for 3 months and then at 6 months and the sclerotia assessed for their viability (% soft and % germination).

Similar pot bioassays to those in sandy loam were set up in silt (Lincolnshire) and peat (Cambridgeshire) soils to determine the effect of raw and composted vegetable waste incorporation on the short and long term viability of sclerotia in these soils.

Control of *Allium* White Rot with Composted Onion Waste (Milestone 4.2)

Onion waste composted for 7 days at 50 ºC was incorporated at a 50% rate into 3 soil types (sandy loam, silt and peat). The soil-waste mixtures were inoculated with 3 conditioned sclerotia (Kirton isolate) per g of mixture and left in a glasshouse for 2 months. This standing period was to simulate the period left between compost application and sowing in the field. After 2 months, pots (7 cm x 7 cm x 8 cm) were filled with the soil-waste mixtures (220 g) and two onion seeds (*Allium cepa*, cultivar White Lisbon) sown per pot. There were 50 replicates per treatment for each soil type arranged in 5 blocks. Control pots with the waste mixtures and soils alone with no sclerotia added were included for comparison (30 replicates per treatment). The pots were assessed weekly for 8 weeks for the presence of white rot, scored as dead plants.

Larger-scale Controlled Composting of Vegetable Waste in Bulk Tunnels (Milestone 5.2)

On the basis of the results obtained from the flask bench-scale experiments, salad onion, bulb onion and sweetcorn, broccoli + onion shale waste was composted in 6 or 20 tonne capacity bulk tunnels at HRI-Wellesbourne for use in field trials to assess the effect of compost application on white rot control.

1. <u>Salad Onion Waste</u>

   Salad onion waste was mixed with straw in a 9:1 ratio to give an 85% moisture content. Urea was added at 4 kg/tonne of mixture and the waste composted for 7 days at 50 ºC.

2. <u>Bulb Onion Waste</u>

   Onion peelings or crushed whole bulbs were mixed with shale in a 10:1 ratio to give an 80% moisture content. Urea was added and the waste mixture composted as described for the salad onion waste. Five bulk tunnel loads of this type of waste mixture (wastes supplied by Goldwood (Moulton) Limited, Bedfordshire Growers Limited and G's Fresh Vegetables Limited) were composted for 1 week during the period July – November.

3. <u>Sweetcorn + Broccoli Waste</u>

   Sweetcorn + broccoli waste was mixed with onion shale in a 2:1 ratio (64% moisture content). Urea was added to the waste mixture, which was composted as described for the salad onion waste.

Field Trials (Milestone 6.2)

1. <u>Salad Onion Waste</u>

   The composted waste produced in the bulk tunnels was applied as a 3 inch layer in July to white rot infested land belonging to one of the industrial partners (JJ Barker Limited) and disced in to 6 inches. Mesh bags containing sclerotia, similar to those used in the pot bioassay, were buried in control and treated areas within the planting depth. Salad onions were sown in September and a sample of the buried sclerotia assessed in November for any effect of the compost application. Retrieved sclerotia were assessed in terms of percentage soft and percentage germination as described in the Annual Report (Year 1). A further sample of sclerotia will be assessed at harvest when incidence of white rot in the field site will be recorded.

2. Bulb Onion Waste

The composted bulb onion waste produced in the bulk tunnels was/will be applied to 3 field sites:

(a) HRI-Kirton

Two month old and freshly made composted waste was applied to plots (1.8 m wide x 10 m long) of white rot infested land in August and bags of sclerotia buried as described previously. A sample of sclerotia was assessed for viability in October. Onions were due to be sown in half of the plots in November (3 month pre-planting treatment) although this has been delayed due to bad weather conditions. The remainder of the plots (7 month pre-planting treatments) will be sown in spring. There are six replicate plots per treatment. The incidence of white rot throughout the growing season and at harvest will be assessed.

(b) Goldwood (Moulton) Limited*

Composted waste will be applied to white rot infested land (Lincolnshire – silt soil) and bags of sclerotia buried as described previously. The effect of the waste application on the sclerotia will be assessed at sowing (spring) and again at harvest when incidence of white rot will be recorded.

(c) Bedfordshire Growers Limited*

Composted waste will be applied to white rot infested land (Bedfordshire – sandy loam soil) and bags of sclerotia buried as described previously. The effect of the waste application on the sclerotia will be assessed at sowing (spring) and again at harvest when incidence of white rot will be recorded.

3. Sweetcorn, Broccoli + Onion Shale Waste*

Composted waste will be applied to white rot infested land (Cambridgeshire – peat soil) belonging to one of the industrial partners (G's Fresh Vegetables Limited) and bags of sclerotia buried as described previously. The effect of the waste application on the sclerotia will be assessed at sowing (spring) and again at harvest when incidence of white rot will be recorded.

* Application of the composted waste has been delayed due to bad weather conditions.

Results

Bench-scale Development and Assessment of a Controlled Composting System for Vegetable Wastes (Milestone 1.2)

Analysis of Salad Onion Waste Supplied by Industrial Partner

The salad onion waste was found to have a slightly higher moisture content (93%) than the bulb onion waste (85-90%) previously analysed.

Composting of Salad Onion Waste

Similar to the bulb onion waste, run-off produced by the salad onion waste varied with the moisture content of the waste mixture. The 80% moisture content mixture produced no run-off although the end product was very dry and straw-like; the 85% moisture content mixture produced some run-off but the mixture was more onion based in appearance; and the 90% moisture content mixture produced considerable run-off (*ca*. 260 ml per 750 g waste). None of the mixtures produced unpleasant odours. On the basis of these results, a mixture with an 85% moisture content was chosen for further work with the salad onion waste in the larger-scale controlled composting in bulk tunnels.

Elimination of Pests from Infested Waste (Milestone 2.1)

Both the onion fly larvae and the nematode, *Steinernema feltiae* were sensitive to the composting conditions (50 °C for 7 days) and were destroyed during the incubation period.

Sclerotia Stimulant Activity of Composted Vegetable Wastes (Milestone 3.2)

Onion Waste Bioassay in Sandy Loam

The results for retrieval of the sclerotia after 1, 2 and 3 months are detailed in the Annual Report (Year 1).

Retrieval of sclerotia after 6 months – The results for the soft sclerotia retrieved after 6 months burial are detailed in Table 1. The 1% rate of the 3 and 7 day old compost produced at 54 °C and the 10% rate of the raw, 3 day old 42 °C and 7 day old 54 °C compost treatments significantly increased the percentage of soft sclerotia retrieved. In addition all treatments at the 50% rate increased percentage soft sclerotia retrieved.

Table 1
Soft sclerotia (%) of *S. cepivorum* retrieved after **6 months** burial in pots of **sandy loam** soil containing different rates of raw or composted onion waste. Values are the mean of three replicate bags each containing 100 sclerotia.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	13.3	22.0	16.7
Raw[a]	17.3	38.7*	41.0*
3 d 42[b]	18.7	38.7*	41.7*
7 d 42[b]	17.0	24.7	36.3*
3 d 54[c]	22.7*	34.3	42.0*
7 d 54[c]	32.0*	54.3*	57.3*
	LSD = 8.0	**LSD = 13.9**	**LSD = 13.5**

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

Similar to the results after 2 and 3 months, the 10% 7 day old 54 °C compost and all the composted treatments at the 50% rate reduced germination of retrieved sclerotia significantly compared with the controls (Table 2).

Table 2
Germination (%) of sclerotia of *S. cepivorum* retrieved after **6 months** burial in pots of **sandy loam** soil containing different rates of raw or composted onion waste. Values are the mean of three replicate bags each containing 100 sclerotia.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	100.0	100.0	99.0
Raw[a]	99.0	100.0	82.3
3 d 42[b]	100.0	100.0	50.0*
7 d 42[b]	100.0	95.3	41.0*
3 d 54[c]	99.0	99.0	9.0*
7 d 54[c]	100.0	88.7*	22.3*
	LSD = 1.3	**LSD = 7.5**	**LSD = 31.3**

At least one of the 10% and 50% rates of the 7 day old 54 ºC onion compost treatment increased soft sclerotia and decreased germination of retrieved sclerotia at every sampling date (1, 2, 3 and 6 months).

Brassica Waste, Carrot Waste + Onion Shale Bioassay in Sandy Loam

The results for the retrieval of the sclerotia after 1 and 2 months are detailed in the Annual Report (Year 1).

Retrieval of sclerotia after 3 months – The results for the soft sclerotia retrieved after 3 months burial in soil-vegetable waste mixtures are detailed in Table 3. The 1% rate of the raw broccoli stalks treatment, all the raw 10% rate treatments and the 50% rate of the raw broccoli stalks, broccoli and cauliflower and wet carrot waste treatments increased soft sclerotia retrieved significantly compared with the control. The effective composted treatments were the 1% rate of the broccoli and cauliflower, the wet carrot wastes and the whole florets of broccoli, the 10% rate of the broccoli stalks and whole carrots, and the 50% rate of the white cabbage and whole carrot treatments.

Table 3
Soft sclerotia (%) of *S. cepivorum* retrieved after **3 months** burial 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.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	4.3	2.3	3.3
Raw BS	15.0 *	18.0*	14.0*
Raw WCAB	8.7	13.3*	5.7
Raw BC	3.7	9.0*	24.3*
Raw WCW	6.3	14.3*	14.7*
Raw WB	6.7	13.7*	8.7
Raw WCAR	7.7	10.7*	4.0
	LSD = 5.7	**LSD = 6.2**	**LSD = 5.8**
Control	1.7	5.0	3.0
7d 50 BS	8.0	24.3*	11.3
7 d 50 WCAB	8.0	10.0	25.0*
7 d 50 BC	12.7*	4.0	11.7
7 d 50 WCW	11.0*	14.0	14.7
7 d 50 WB	8.7*	5.0	10.3
7 d 50 WCAR	4.7	27.0*	24.0*
	LSD = 7.0	**LSD = 10.6**	**LSD = 11.8**

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

Table 4 details the effect of the vegetable wastes on germination of retrieved sclerotia. The raw wet carrot waste treatment at the 50% rate was the only raw waste treatment to have a significant effect on germination. This treatment had a similar effect after only 1 and 2 months. The composted treatments were more effective than the raw waste. The 1% rate of the white cabbage, 10% rate of the wet carrot wastes and the 50% rate of the broccoli and cauliflower, wet carrot wastes, whole florets of broccoli and the whole carrot treatments all reduced germination significantly compared with the controls with a number of the treatments also shown to be effective after 2 months.

Table 4

Germination (%) of sclerotia of *S. cepivorum* retrieved after **3 months** burial 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.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	88.0	96.7	99.0
Raw BS	81.3	92.0	96.7
Raw WCAB	81.0	100.0	98.0
Raw BC	99.0	97.7	82.3
Raw WCW	100.0	96.7	65.7*
Raw WB	99.0	91.0	86.7
Raw WCAR	99.0	97.7	94.7
	LSD = 21.9	**LSD = 7.1**	**LSD = 17.4**
Control	96.7	96.7	98.0
7 d 50 BS	89.0	98.0	74.7
7 d 50 WCAB	65.7*	98.0	70.0
7 d 50 BC	98.0	98.0	51.0*
7 d 50 WCW	99.0	65.7*	51.0*
7 d 50 WB	90.0	100.0	51.0*
7 d 50 WCAR	95.7	95.3	43.3*
	LSD = 14.1	**LSD = 28.3**	**LSD = 38.6**

Control = no added waste
Raw = raw waste
7 d 50 = waste composted for 7 days at 50 °C
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 6 months - The results for the percentage of soft sclerotia retrieved after 6 months burial in sandy loam containing raw or composted vegetable waste are detailed in Table 5. There were a number of effective raw and composted treatments (1% raw white cabbage and whole carrots, 10% raw broccoli and cauliflower, and whole florets of broccoli, 10% composted broccoli stalks, wet carrot waste and whole carrots, 50% raw and composted broccoli stalks, raw and composted white cabbage, raw broccoli and cauliflower, raw and composted wet carrot waste, raw and composted whole florets of broccoli, and composted whole carrots). There did not appear to be a best material although the composted whole carrot treatment was found to increase percentage soft sclerotia retrieved significantly at the 10% and 50% rates after 2, 3 and 6 months burial.

Table 5
Soft sclerotia (%) of *S. cepivorum* retrieved after **6 months** burial 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.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	6.3	9.6	4.0
Raw BS	9.7	20.0	25.3*
Raw WCAB	13.7*	12.7	15.7*
Raw BC	5.3	25.0*	17.7*
Raw WCW	5.3	11.3	29.0*
Raw WB	7.3	20.3*	20.7*
Raw WCAR	14.0*	11.7	13.3
	LSD = 6.5	**LSD = 10.5**	**LSD = 11.0**
Control	9.7	3.3	2.7
7d 50 BS	11.3	23.0*	19.7*
7 d 50 WCAB	8.3	12.7	36.7*
7 d 50 BC	15.0	8.0	10.7
7 d 50 WCW	9.3	20.0*	25.0*
7 d 50 WB	9.7	5.7	27.8*
7 d 50 WCAR	8.3	25.7*	26.0*
	LSD = 5.8	**LSD = 11.4**	**LSD = 11.4**

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 results of the effect of the treatments on percentage germination of sclerotia retrieved are detailed in Table 6. The 50% rate of the composted treatments was most effective with every treatment except the broccoli stalks decreasing percentage germination significantly compared with the control. In addition the 10% and 50% raw whole florets of broccoli and the 50% raw and 10% composted wet carrot waste treatments also reduced germination. A number of these treatments were shown to be effective after 3 months with the 50% raw wet carrot waste effective after 1, 2, 3 and 6 months.

Table 6

Germination (%) of sclerotia of *S. cepivorum* retrieved after **6 months** burial 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.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	98.0	100.0	99.0
Raw BS	99.0	95.3	99.0
Raw WCAB	99.0	99.0	97.7
Raw BC	95.7	95.7	80.0
Raw WCW	100.0	94.3	67.7*
Raw WB	99.0	92.3*	72.3*
Raw WCAR	97.7	96.7	94.3
	LSD = 3.7	**LSD = 6.8**	**LSD = 26.3**
Control	98.0	100.0	100.0
7 d 50 BS	99.0	99.0	82.3
7 d 50 WCAB	95.7	100.0	52.3*
7 d 50 BC	75.7	100.0	42.3*
7 d 50 WCW	100.0	96.7*	51.0*
7 d 50 WB	77.7	99.0	38.7*
7 d 50 WCAR	100.0	99.0	22.0*
	LSD = 24.9	**LSD = 2.0**	**LSD = 28.3**

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

Onion and Other Vegetable Waste Bioassay in Silt

Retrieval of sclerotia after 1 month – Table 7 details the percentage of soft sclerotia retrieved after 1 month burial in soil-vegetable waste mixtures. The effect of the waste incorporation was minimal after 1 month with only the 10% composted onion waste treatment increasing percentage soft sclerotia retrieved significantly compared with the control.

Table 7
Soft sclerotia (%) of *S. cepivorum* retrieved after **1 month** burial in pots of **silt** 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.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	13.0	12.7	15.0
Raw WCAB	13.3	30.7	27.0
Raw WB	12.0	18.7	9.7
Raw WCAR	14.7	22.3	12.3
Raw O	11.0	30.0	19.7
	LSD = 11.8	**LSD = 33.1**	**LSD = 23.1**
Control	7.7	9.0	8.3
7d 50 WCAB	6.0	6.3	17.7
7d 50 WB	9.3	8.3	15.7
7d 50 WCAR	4.7	14.7	4.7
7d 50 O	5.7	29.7*	16.7
	LSD = 9.5	**LSD = 16.0**	**LSD = 21.5**

Raw = raw waste
7 d 50 = waste composted for 7 days at 50 ºC
WCAB = White Cabbage
WB = Whole florets of Broccoli
WCAR = Whole Carrots
O = Onion peelings

The effect of the treatments on germination of retrieved sclerotia was minimal after 1 month burial with only the 50% rate of the raw whole florets of broccoli and the composted onion peelings treatments reducing germination significantly compared with the control (Table 8).

Table 8
Germination (%) of sclerotia of *S. cepivorum* retrieved after **1 month** burial in pots of **silt** 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.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	83.3	91.3	83.0
Raw WCAB	84.7	75.7	63.3
Raw WB	85.3	81.3	29.0*
Raw WCAR	91.0	83.3	72.3
Raw O	81.3	81.3	81.0
	LSD = 24.0	**LSD = 31.9**	**LSD = 51.5**
Control	83.3	89.0	83.0
7d 50 WCAB	94.7	95.7	89.0
7d 50 WB	95.7	94.3	74.7
7d 50 WCAR	91.0	93.3	64.3
7d 50 O	81.3	84.7	53.3*
	LSD = 8.7	**LSD = 20.1**	**LSD = 24.7**

Raw = raw waste
7 d 50 = waste composted for 7 days at 50 ºC
WCAB = White Cabbage
WB = Whole florets of Broccoli
WCAR = Whole Carrots
O = Onion peelings

Retrieval of sclerotia after 2 months – Table 9 details the percentage of soft sclerotia retrieved after 2 months burial in soil-vegetable waste mixtures. The raw and composted onion waste at the 10% and 50% incorporation rates increased the percentage of soft sclerotia retrieved. In addition the 10% and 50% rates of the raw white cabbage and the 10% raw whole carrot treatments had a significant effect.

Table 9

Soft sclerotia (%) of *S. cepivorum* retrieved after **2 months** burial in pots of **silt** 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.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	9.7	14.3	7.0
Raw WCAB	15.6	27.0*	33.0*
Raw WB	12.3	15.3	11.7
Raw WCAR	12.3	27.3*	13.3
Raw O	13.3	27.3*	29.0*
	LSD = 8.3	**LSD = 11.1**	**LSD = 7.2**
Control	11.0	10.3	8.0
7d 50 WCAB	6.0	12.3	14.7
7d 50 WB	6.0	12.3	17.7
7d 50 WCAR	7.7	8.3	17.3
7d 50 O	12.7	31.0*	22.3*
	LSD = 5.2	**LSD = 10.3**	**LSD = 12.1**

Raw = raw waste
7 d 50 = waste composted for 7 days at 50 °C
WCAB = White Cabbage
WB = Whole florets of Broccoli
WCAR = Whole Carrots
O = Onion peelings

Similar to the results after 1 month, the effect of the treatments after 2 months on germination of retrieved sclerotia was minimal with only the 10% and 50% rates of the raw whole florets of broccoli treatment reducing germination significantly compared with the control (Table 10).

Table 10
Germination (%) of sclerotia of *S. cepivorum* retrieved after **2 months** burial in pots of **silt** 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.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	84.7	89.0	90.0
Raw WCAB	90.0	86.7	70.0
Raw WB	83.7	68.7*	51.0*
Raw WCAR	87.7	86.7	65.0
Raw O	95.7	88.7	71.3
	LSD = 12.4	**LSD = 18.6**	**LSD = 29.6**
Control	87.0	77.7	81.3
7d 50 WCAB	95.3	90.0	75.7
7d 50 WB	95.7	94.3	73.3
7d 50 WCAR	94.7	95.7	66.7
7d 50 O	85.7	67.0	71.3
	LSD = 7.8	**LSD = 15.4**	**LSD = 21.2**

Raw = raw waste
7 d 50 = waste composted for 7 days at 50 °C
WCAB = White Cabbage
WB = Whole florets of Broccoli
WCAR = Whole Carrots
O = Onion peelings

Retrieval of sclerotia after 3 months – Similar to the 2 month results, the 10% and 50% raw and 10% composted onion treatments and the 10% raw white cabbage treatment increased percentage soft sclerotia retrieved (Table 11). In addition, all the composted treatments at the 10% incorporation rate were significantly different from the control.

Table 11
Soft sclerotia (%) of *S. cepivorum* retrieved after **3 months** burial in pots of **silt** 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.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	17.7	11.7	14.3
Raw WCAB	11.3	27.7*	30.0
Raw WB	10.0	21.3	10.3
Raw WCAR	6.0	18.3	17.0
Raw O	9.3	22.0*	31.3*
	LSD = 5.9	**LSD = 10.2**	**LSD = 15.9**
Control	10.7	10.7	15.3
7d 50 WCAB	3.0	12.3*	15.0
7d 50 WB	5.7	13.3*	16.0
7d 50 WCAR	6.3	13.7*	19.3
7d 50 O	5.3	31.0*	13.7
	LSD = 3.7	**LSD = 1.4**	**LSD = 8.2**

Raw = raw waste
7 d 50 = waste composted for 7 days at 50 °C
WCAB = White Cabbage
WB = Whole florets of Broccoli
WCAR = Whole Carrots
O = Onion peelings

The results for the effect of the vegetable waste on sclerotia germination are detailed in Table 12. A larger number of treatments were found to be effective at reducing germination after 3 months (50% raw whole florets of broccoli, 10% composted onion peelings, 50% composted whole florets of broccoli, whole carrots and onion peelings) in comparison with the 1 and 2 month results, with the 50% rate treatments being the most effective.

Table 12
Germination (%) of sclerotia of *S. cepivorum* retrieved after **3 months** burial in pots of **silt** 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.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	92.0	93.3	86.6
Raw WCAB	83.3	77.7	65.0
Raw WB	92.3	86.0	29.0*
Raw WCAR	94.7	93.3	66.7
Raw O	94.7	93.0	77.3
	LSD = 9.9	**LSD = 18.2**	**LSD = 29.6**
Control	89.0	96.7	94.7
7d 50 WCAB	97.7	97.7	85.7
7d 50 WB	93.3	98.0	67.0*
7d 50 WCAR	99.0	95.7	70.0*
7d 50 O	100.0	82.3*	55.7*
	LSD = 6.5	**LSD = 10.4**	**LSD = 22.4**

Raw = raw waste
7 d 50 = waste composted for 7 days at 50 ºC
WCAB = White Cabbage
WB = Whole florets of Broccoli
WCAR = Whole Carrots
O = Onion peelings

Retrieval of sclerotia after 6 months – Table 13 details the percentage of soft sclerotia retrieved after 6 months burial in the soil-vegetable waste mixtures. There were a number of effective treatments: 50% raw whole florets of broccoli and whole carrots, 10% composted onion peelings, 50% composted whole florets of broccoli, 50% raw onion peelings and 10% raw white cabbage. The latter 2 treatments also had a significant effect after 2 and 3 months.

Table 13
Soft sclerotia (%) of *S. cepivorum* retrieved after **6 months** burial in pots of **silt** 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.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	17.0	11.3	13.6
Raw WCAB	16.7	31.3*	22.3
Raw WB	18.3	17.0	36.7*
Raw WCAR	11.0	15.3	32.0*
Raw O	11.0	20.3	47.7*
	LSD = 7.1	**LSD = 12.0**	**LSD = 14.9**
Control	13.7	10.7	13.0
7d 50 WCAB	8.7	8.7	26.0
7d 50 WB	5.3	10.7	32.3*
7d 50 WCAR	4.0	13.0	23.5
7d 50 O	7.7	39.3*	28.7
	LSD = 5.0	**LSD = 11.3**	**LSD = 16.0**

Raw = raw waste
7 d 50 = waste composted for 7 days at 50 ºC
WCAB = White Cabbage
WB = Whole florets of Broccoli
WCAR = Whole Carrots
O = Onion peelings

The 50% incorporation rate of the waste was the most effective in reducing germination of retrieved sclerotia, with all the raw waste treatments and the composted whole florets of broccoli and onion treatments significantly different from the control (Table 14). In addition, the 1% raw white cabbage treatment significantly reduced germination.

Table 14

Germination (%) of sclerotia of *S. cepivorum* retrieved after **6 months** burial in pots of **silt** 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.

Treatment	1% Waste	10% Waste	50% Waste
Control	97.0	98.0	98.0
Raw WCAB	72.0*	91.3	66.7*
Raw WB	94.3	97.7	42.3*
Raw WCAR	96.7	100.0	54.0*
Raw O	97.7	88.0	62.3*
	LSD = 22.3	**LSD = 14.2**	**LSD = 27.4**
Control	97.7	94.7	99.0
7d 50 WCAB	99.0	100.0	79.0
7d 50 WB	98.0	99.0	56.0*
7d 50 WCAR	97.7	96.7	85.0
7d 50 O	95.7	98.0	55.0*
	LSD = 4.2	**LSD = 5.5**	**LSD = 40.1**

Raw = raw waste
7 d 50 = waste composted for 7 days at 50 ºC
WCAB = White Cabbage
WB = Whole florets of Broccoli
WCAR = Whole Carrots
O = Onion peelings

Retrieval of sclerotia after 9 months – Table 15 details the percentage of soft sclerotia retrieved after 9 months burial in the soil-vegetable waste mixtures. Similar to the 6 month results, there were a number of effective treatments. The 10% and 50% incorporation rates of all the raw wastes increased the percentage of soft sclerotia retrieved. In addition, the 10% rate of the composted onion peelings treatment and the 50% rates of the composted white cabbage, whole florets of broccoli and whole carrots treatments had a significant effect.

Table 15
Soft sclerotia (%) of *S. cepivorum* retrieved after **9 months** burial in pots of **silt** 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.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	16.3	13.3	15.7
Raw WCAB	14.7	29.7*	37.0*
Raw WB	16.7	32.3*	29.7*
Raw WCAR	9.3	26.7*	29.7*
Raw O	12.7	29.7*	40.0*
	LSD = 9.0	**LSD = 8.5**	**LSD = 12.1**
Control	18.0	13.0	12.7
7d 50 WCAB	9.0	17.0	27.0*
7d 50 WB	5.7	12.7	29.7*
7d 50 WCAR	7.3	21.0	23.3*
7d 50 O	11.3	43.0*	22.0
	LSD = 8.4	**LSD = 11.8**	**LSD = 10.0**

Raw = raw waste
7 d 50 = waste composted for 7 days at 50 ºC
WCAB = White Cabbage
WB = Whole florets of Broccoli
WCAR = Whole Carrots
O = Onion peelings

The results for the germination of sclerotia retrieved after 9 months burial are detailed in Table 16. The 1% and 10% rates had no effect on germination. All treatments at the 50% rate, with the exception of the raw white cabbage treatment, reduced germination significantly compared with the control.

Table 16
Germination (%) of sclerotia of *S. cepivorum* retrieved after **9 months** burial in pots of **silt** 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.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	95.7	94.3	95.3
Raw WCAB	92.0	97.7	77.0
Raw WB	96.7	93.3	47.7*
Raw WCAR	98.0	99.0	31.0*
Raw O	97.3	91.0	71.0*
	LSD = 6.8	**LSD = 8.2**	**LSD = 23.4**
Control	95.7	92.0	99.0
7d 50 WCAB	99.0	98.5	67.7*
7d 50 WB	99.0	99.0	43.0*
7d 50 WCAR	100.0	96.7	47.3*
7d 50 O	99.0	92.7	57.7*
	LSD = 5.1	**LSD = 8.1**	**LSD = 30.3**

Raw = raw waste
7 d 50 = waste composted for 7 days at 50 °C
WCAB = White Cabbage
WB = Whole florets of Broccoli
WCAR = Whole Carrots
O = Onion peelings

Retrieval of sclerotia after 12 months – The results for the percentage of soft sclerotia retrieved after 12 months burial in the soil-vegetable waste mixtures are detailed in Table 17. All treatments at the 50% rate increased percentage soft sclerotia retrieved. The 10% rate was also shown to be effective with most treatments increasing percentage soft sclerotia retrieved compared with the control.

Table 17

Soft sclerotia (%) of *S. cepivorum* retrieved after **12 months** burial in pots of **silt** 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.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	23.7	19.3	22.7
Raw WCAB	19.0	76.0*	89.3*
Raw WB	18.3	49.5*	87.0*
Raw WCAR	18.0	26.0	88.7*
Raw O	13.7	74.7*	94.0*
	LSD = 9.3	**LSD = 18.6**	**LSD = 7.4**
Control	16.0	11.0	16.3
7d 50 WCAB	11.3	14.0	75.7*
7d 50 WB	16.3	21.3*	75.0*
7d 50 WCAR	10.0	18.7*	39.3*
7d 50 O	11.3	81.3*	74.7*
	LSD = 5.5	**LSD = 7.6**	**LSD = 14.5**

Raw = raw waste
7 d 50 = waste composted for 7 days at 50 °C
WCAB = White Cabbage
WB = Whole florets of Broccoli
WCAR = Whole Carrots
O = Onion peelings

Table 18 details the results for the germination of sclerotia retrieved after 12 months burial. The 50% rate was the most effective with five treatments (raw and composted whole florets of broccoli, raw and composted whole carrots, and raw onion peelings) reducing germination of retrieved sclerotia significantly compared with the control.

Table 18
Germination (%) of sclerotia of *S. cepivorum* retrieved after **12 months** burial in pots of **silt** 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.

Treatment	1% Waste	10% Waste	50% Waste
Control	96.7	95.7	91.3
Raw WCAB	84.3*	89.0	84.3
Raw WB	100.0	90.5	43.3*
Raw WCAR	100.0	100.0	49.7*
Raw O	96.7	80.3*	49.0*
	LSD = 12.1	**LSD = 11.4**	**LSD = 38.6**
Control	99.0	100.0	94.3
7d 50 WCAB	100.0	99.0	83.3
7d 50 WB	95.7	96.7	54.3*
7d 50 WCAR	92.3	99.0	56.7*
7d 50 O	99.0	95.0	76.0
	LSD = 8.4	**LSD = 6.7**	**LSD = 30.6**

Raw = raw waste
7 d 50 = waste composted for 7 days at 50 °C
WCAB = White Cabbage
WB = Whole florets of Broccoli
WCAR = Whole Carrots
O = Onion peelings

Onion and Other Vegetable Waste Bioassay in Peat

Retrieval of sclerotia after 1 month - Table 19 details the percentage of soft sclerotia retrieved after 1 month burial in the soil-vegetable waste mixtures. The effect of the waste incorporation was minimal after 1 month with only the 50% raw and composted onion waste treatments increasing percentage soft sclerotia retrieved significantly compared with the control.

Table 19
Soft sclerotia (%) of *S. cepivorum* retrieved after **1 month** burial in pots of **peat** 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.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	2.8	1.0	1.8
Raw WCAB	3.0	2.7	2.7
Raw WB	1.3	4.0	2.3
Raw WCAR	1.0	3.3	2.0
Raw O	3.3	2.0	9.0*
	LSD = 4.6	**LSD = 4.7**	**LSD = 4.9**
Control	2.8	1.0	1.8
7d 50 WCAB	2.3	3.0	2.7
7d 50 WB	0.3	2.7	2.3
7d 50 WCAR	1.0	1.0	2.0
7d 50 O	1.0	4.7	5.3*
	LSD = 2.6	**LSD = 4.3**	**LSD = 3.4**

Raw = raw waste
7 d 50 = waste composted for 7 days at 50 ºC
WCAB = White Cabbage
WB = Whole florets of Broccoli
WCAR = Whole Carrots
O = Onion peelings

The results for the germination of sclerotia retrieved after 1 month burial are detailed in Table 20. The 10% composted onion peelings, 50% raw and composted onion peelings, and the 1% and 10% raw whole florets of broccoli treatments reduced germination significantly compared with the control.

Table 20

Germination (%) of *S. cepivorum* retrieved after **1 month** burial in pots of **peat** 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.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	95.0	95.3	91.8
Raw WCAB	92.3	92.3	90.0
Raw WB	78.0*	78.7*	84.7
Raw WCAR	93.3	86.3	92.3
Raw O	94.7	89.0	75.3*
	LSD =11.1	**LSD = 13.0**	**LSD = 15.7**
Control	95.0	95.3	91.8
7d 50 WCAB	94.7	96.7	86.7
7d 50 WB	86.7	81.0	91.3
7d 50 WCAR	94.3	87.7	83.3
7d 50 O	87.0	74.3*	78.7*
	LSD = 9.2	**LSD = 16.0**	**LSD = 11.5**

Raw = raw waste
7 d 50 = waste composted for 7 days at 50 °C
WCAB = White Cabbage
WB = Whole florets of Broccoli
WCAR = Whole Carrots
O = Onion peelings

Retrieval of sclerotia after 2 months – The results for the percentage of soft sclerotia retrieved after 2 months burial in the soil-vegetable waste mixtures are detailed in Table 21. Similar to the 1 month results, the effect of the treatments was minimal with only the 1% rate of the white cabbage and the 10% rate of the composted onion peelings treatments having a significant effect.

Table 21
Soft sclerotia (%) of *S. cepivorum* retrieved after **2 months** burial in pots of **peat** 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.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	1.0	2.3	4.0
Raw WCAB	3.3	4.7	10.0
Raw WB	2.0	3.0	0
Raw WCAR	1.7	2.0	2.3
Raw O	1.3	0.7	9.0
	LSD = 2.8	**LSD = 3.5**	**LSD = 6.2**
Control	1.0	2.3	4.0
7d 50 WCAB	8.0*	6.0	3.0
7d 50 WB	0.7	4.7	2.0
7d 50 WCAR	1.3	1.3	6.0
7d 50 O	5.7	10.7*	4.3
	LSD = 6.0	**LSD = 5.8**	**LSD = 6.2**

Raw = raw waste
7 d 50 = waste composted for 7 days at 50 °C
WCAB = White Cabbage
WB = Whole florets of Broccoli
WCAR = Whole Carrots
O = Onion peelings

No effect on germination of retrieved sclerotia was recorded after 2 months burial (Table 22).

Table 22

Germination (%) of *S. cepivorum* retrieved after **2 months** burial in pots of **peat** 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.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	89.3	91.0	97.5
Raw WCAB	85.3	93.7	89.3
Raw WB	96.3	87.0	86.3
Raw WCAR	84.7	92.3	89.0
Raw O	86.0	87.0	83.0
	LSD = 6.8	**LSD = 8.6**	**LSD = 32.7**
Control	89.3	91.0	97.5
7d 50 WCAB	88.7	91.0	90.0
7d 50 WB	92.7	84.3	94.5
7d 50 WCAR	95.3	87.7	85.7
7d 50 O	95.0	84.3	76.0
	LSD = 7.2	**LSD = 8.3**	**LSD = 39.9**

Raw = raw waste
7 d 50 = waste composted for 7 days at 50 °C
WCAB = White Cabbage
WB = Whole florets of Broccoli
WCAR = Whole Carrots
O = Onion peelings

Retrieval of sclerotia after 3 months – The results for the percentage of soft sclerotia retrieved after 3 months burial in the soil-vegetable waste mixtures are detailed in Table 23. The number of effective treatments increased in comparison to the 1 and 2 month results. Three of the onion peelings treatments (1% and 10% raw and 10% composted) and the 1% raw and composted whole florets of broccoli treatments had a significant effect.

Table 23
Soft sclerotia (%) of *S. cepivorum* retrieved after **3 months** burial in pots of **peat** 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.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	0.5	1.5	6.5
Raw WCAB	2.7	5.0	7.3
Raw WB	4.7*	4.7	1.0
Raw WCAR	3.0	5.3	2.7
Raw O	6.0*	9.7*	9.0
	LSD = 3.6	**LSD = 5.0**	**LSD = 5.5**
Control	0.5	1.5	6.5
7d 50 WCAB	2.3	3.3	4.0
7d 50 WB	4.3*	9.3	2.7
7d 50 WCAR	2.3	0.7	4.7
7d 50 O	3.0	11.0*	5.3
	LSD = 3.2	**LSD = 7.9**	**LSD = 2.8**

Raw = raw waste
7 d 50 = waste composted for 7 days at 50 ºC
WCAB = White Cabbage
WB = Whole florets of Broccoli
WCAR = Whole Carrots
O = Onion peelings

A number of treatments had a significant effect on germination of sclerotia retrieved after 3 months burial (Table 24). Similar to the results for soft sclerotia, the onion peelings treatments were the most effective with the 10% and 50% raw, and all 3 rates of the composted treatments having a significant effect.

Table 24

Germination (%) of *S. cepivorum* retrieved after **3 months** burial in pots of **peat** 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.

Treatment	1% Waste	10% Waste	50% Waste
Control	98.7	96.7	96.0
Raw WCAB	91.3*	90.7	87.3
Raw WB	97.3	98.0	43.3*
Raw WCAR	94.3	90.3	93.3
Raw O	98.0	85.7*	41.7*
	LSD = 6.8	**LSD = 7.1**	**LSD = 28.8**
Control	98.7	96.7	96.0
7d 50 WCAB	92.0	98.0	85.7
7d 50 WB	87.0*	87.3*	86.0
7d 50 WCAR	96.7	96.7	86.7
7d 50 O	89.0*	69.0*	67.0*
	LSD = 8.9	**LSD = 8.5**	**LSD = 23.8**

Raw = raw waste
7 d 50 = waste composted for 7 days at 50 °C
WCAB = White Cabbage
WB = Whole florets of Broccoli
WCAR = Whole Carrots
O = Onion peelings

Retrieval of sclerotia after 6 months – The results for the percentage of soft sclerotia retrieved after 6 months burial in the soil-vegetable waste mixtures are detailed in Table 25. There were 5 effective treatments (1% and 50% raw whole florets of broccoli, 1% and 50% raw onion peelings, and 10% composted onion peelings) although there was no clear trend with treatment and rate of incorporation.

Table 25
Soft sclerotia (%) of *S. cepivorum* retrieved after **6 months** burial in pots of **peat** 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.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	3.8	6.5	9.8
Raw WCAB	4.7	9.0	8.3
Raw WB	9.7*	17.0	23.0*
Raw WCAR	3.0	9.3	6.7
Raw O	10.3*	21.3	31.7*
	LSD = 3.9	**LSD = 21.8**	**LSD = 11.9**
Control	3.8	6.5	9.8
7d 50 WCAB	9.3	7.3	15.7
7d 50 WB	5.3	8.3	7.3
7d 50 WCAR	6.0	5.3	16.3
7d 50 O	8.0	27.3*	19.3
	LSD = 6.3	**LSD = 6.2**	**LSD = 19.1**

Raw = raw waste
7 d 50 = waste composted for 7 days at 50 °C
WCAB = White Cabbage
WB = Whole florets of Broccoli
WCAR = Whole Carrots
O = Onion peelings

The effect of the treatments on the germination of sclerotia retrieved after 6 months was, in comparison to the 3 month results, surprisingly minimal with only the 50% raw whole florets of broccoli treatment having a significant effect (Table 26).

Table 26

Germination (%) of *S. cepivorum* retrieved after **6 months** burial in pots of **peat** 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.

Treatment	**1% Waste**	**10% Waste**	**50% Waste**
Control	94.3	91.0	95.0
Raw WCAB	97.0	93.3	91.0
Raw WB	90.0	95.3	39.0*
Raw WCAR	95.3	89.0	78.7
Raw O	97.7	89.7	82.7
	LSD = 6.6	**LSD = 8.8**	**LSD = 23.0**
Control	94.3	91.0	95.0
7d 50 WCAB	91.0	95.7	92.7
7d 50 WB	100.0	92.3	70.7
7d 50 WCAR	96.7	97.7	86.7
7d 50 O	94.0	90.0	64.5
	LSD = 6.2	**LSD = 9.2**	**LSD = 36.2**

Raw = raw waste
7 d 50 = waste composted for 7 days at 50 ºC
WCAB = White Cabbage
WB = Whole florets of Broccoli
WCAR = Whole Carrots
O = Onion peelings

Control of *Allium* White Rot with Composted Onion Waste (Milestone 4.2)

The results for the pot bioassay testing the control of *Allium* white rot with composted onion waste are detailed in Table 27. The plants were 3 weeks old before any disease was detected and no disease was detected in the plants in the silt soil until week 6. The percentage of diseased plants increased over time, most noticeably in the control treatments in the sandy loam and peat soils. Due to variability between replicate blocks, only the compost treatment in the peat soil had a significant effect on disease control after 5 weeks. This control continued to 8 weeks when the experiment was terminated. No disease was detected in the uninoculated pots. The disease incidence in the controls of the sandy loam and silt soils was much lower than in the peat soil. This suggests that the population density of sclerotia in the sandy loam and silt soils may need to be increased to achieve similar levels of disease incidence to the peat soil. This bioassay will be repeated to try to improve the uniformity of disease and hence reduce the variability between blocks.

Table 27

Onion plants (%) infected with *Allium* white rot in 3 soil types (sandy loam, silt and peat) containing composted onion waste (50% incorporation rate) inoculated with 3 sclerotia/g of mixture. Values are the mean of 50 replicate pots each containing 2 onion seeds. Control = soil only. Test = 50% soil + 50% composted onion waste.

Week	**Sandy Loam**		**Silt**		**Peat**	
	Control	Test	Control	Test	Control	Test
2	0	0	0	0	0	0
3	2	7	0	0	4	0
4	6	10	0	0	16	2
5	18	10	0	0	29	5*
6	18	11	1	7	48	10*
7	22	14	6	7	70	13*
8	24	14	7	7	82	17*

Larger-scale Controlled Composting of Vegetable Waste in Bulk Tunnels (Milestone 5.2)

The different waste types composted well in the bulk tunnels with no unpleasant odours produced outside the tunnels during the composting period. Run-off collected was minimal in comparison to the volume of waste composted (Table 28). A large reduction in the volume of the salad onion and broccoli + sweetcorn wastes was noted within 24 hours of commencing composting. At the end of the composting period these wastes had visibly reduced in volume by *ca.* 50%. This visual assessment was confirmed by measurement (Table 28). The weight of the waste also reduced during composting. Weight loss varied with the type of waste, ranging from 4-50% (Table 28).

Table 28
Weight loss (%), volume loss (%) and run-off (l $tonne^{-1}$) from vegetable waste composted for 7 days at 50 ºC in 6 or 20 tonne bulk capacity tunnels.
- = not determined.

Vegetable Waste	**Initial Weight of Waste (kg)**	**Weight Loss (%)**	**Initial Volume of Waste (m^3)**	**Volume Loss (%)**	**Volume of run-off (l $tonne^{-1}$)**
Salad onion + straw	2475	50	-	-	-
Onion peelings + shale (1)	4131	16	-	-	26
(2)	5000	-	-	-	18
(3)	10,000	-	-	-	-
(4)	2934	4	17	68	-
Crushed whole onions + shale	5750	17	17	50	-
Broccoli + sweetcorn + onion shale	1660	37	9	46	-

Field Trials (Milestone 6.2)

1. Salad Onion Waste

The results for the percentage of soft sclerotia and germination of sclerotia retrieved after 3 months burial in 50% salad onion + straw waste (composted) are detailed in Table 29. The presence of the waste had no effect on the viability of the sclerotia at this stage of the trial.

Table 29
Soft sclerotia (%) and germination (%) of sclerotia of *S. cepivorum* retrieved after 3 months burial in a field site with composted spring onion + straw waste applied and incorporated to a 50% rate (Test). Values are the mean of 10 replicate bags each containing 100 sclerotia.

Treatment	**Soft**	**Germination**
Control	1.9	95.0
Test	0.4	94.3
	LSD = 3.4	**LSD = 10.5**

2. Bulb Onion Waste

(a) HRI-Kirton

The results for the percentage of soft sclerotia and germination of sclerotia retrieved after 2 months burial in 50% fresh or stored composted onion waste are detailed in Table 30. The presence of the waste had no effect on the viability of the sclerotia at this stage of the trial

Table 30

Soft sclerotia (%) and germination (%) of sclerotia of *S. cepivorum* retrieved after 2 months burial in a field site at HRI-Kirton. Values are the mean of six replicate bags each containing 100 sclerotia.

Treatment[a]	**Soft Sclerotia**	**Germination**
A	1.0	97.2
B	3.3	89.5
E	1.7	97.3
F	0.5	99.5
G	1.2	95.0
J	0.8	98.8
	LSD = 3.1	**LSD = 10.3**

a = treatment codes

	Onion Planting	**Compost Application**	**Date of Application**	**Compost**
A	Autumn	3 months preplanting	August	Stored
B	Autumn	3 months preplanting	August	Fresh
E	Spring	7 months preplanting	August	Stored
F	Spring	7 months preplanting	August	Fresh
G	Autumn	None	Untreated control	
J	Autumn	None	Folicur dipped sets plus sprays	

Discussion

Milestone 1.2 - The moisture content of the salad onion waste was slightly higher than the bulb onion waste previously analysed. Similar to the bulb onion waste however, a salad onion and straw 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. The composted salad onion waste mixture produced under these conditions was very dry and the onion waste composition was quite low. The moisture content of the salad onion mixture prepared for bulk tunnel composting was therefore raised to 85% to increase the onion content of the end product. This mixture produced some run-off (*ca*. 50 ml per 750 g waste) and no unpleasant odours.

Milestone 2.1 - The composting conditions (7 days at 50 ºC) previously found to destroy sclerotia of *S. cepivorum* and resting spores of *O. brassicae*, were also found to destroy 5 day old onion fly larvae and the nematode, *Steinernema feltiae*. This indicates that vegetable waste composted under these conditions should be free of these pathogens and pests and hence safe to apply to land.

Milestone 3.2 - The results for the effect of vegetable waste on the viability of sclerotia in the silt soil bioassay were similar to the sandy loam bioassay in that the effect of the waste types was 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 contrast, the results for the effect of the vegetable wastes on sclerotia viability in the peat soil bioassay showed no clear trend with rate of incorporation or duration of exposure. The reason(s) for this difference between soil types is not clear but may be that properties of the peat soil, such as the pH, and/or its composition somehow preserve the sclerotia.

Milestone 4.2 - Good control of *Allium* white rot with composted onion waste was achieved in the pot bioassay with the peat soil. The levels of disease in the control plants in the sandy loam and silt soils were low in comparison to those in the peat soil. Thus, any control effect of the compost treatments in the sandy loam and silt soils was difficult to detect. This bioassay will therefore be repeated to try to improve the uniformity of disease levels and reduce variability between replicates.

Milestone 5.2 - Flask scale experiments in Year 1 of the project identified vegetable mixtures and composting conditions which minimised run-off and odours produced. In Year 2 of the project these parameters were applied to composting vegetable waste on a large scale in bulk tunnels. The wastes in the bulk tunnels composted well under these conditions, with the volume of waste reducing by up to 68% and weight loss ranging from 4-50%. In addition, similar to the flask scale experiments, the wastes in the bulk tunnels produced minimal run-off and no unpleasant odours.

Milestone 6.2 - In contrast to the results from the pot bioassays in the three soil types (sandy loam, silt and peat), no effect of composted vegetable waste incorporation on sclerotia viability was recorded after 2 or 3 months exposure in two field trials. It is not unusual for field trial results to differ from those obtained in glasshouse trials due to the variability in environmental conditions in the field. The sclerotia in the field trials were exposed to the waste from August to October and it may be that soil temperatures were lower than optimum to achieve an effect on sclerotial viability.

Conclusions

1. Salad onion waste has a slightly higher moisture content (93%) than bulb onion waste (85-90%).

2. Similar to the bulb onion waste, a salad onion and straw waste mixture prepared to an 80% moisture content is optimal in minimising run-off and odours produced during composting at 50 ºC for 7 days. A salad onion and straw mixture with a slightly higher moisture content (85%) however was considered more practical for large scale composting to increase the onion content of the mixture. This mixture produces some run-off but has no unpleasant odours.

3. Five day old onion fly larvae and the nematode, *Steinernema feltiae*, are destroyed by a temperature of 50 ºC held for 7 days in composting onion waste.

4. In pot bioassays, the effect of composted vegetable waste (onion, *Brassica* and carrot) in sandy loam and silt soils on the viability of sclerotia of *S. cepivorum* is dependent on the 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.

5. The viability of sclerotia in peat soil is influenced by the presence of composted vegetable waste (onion, *Brassica* and carrot) although there is no relationship between rate of incorporation or duration of exposure on the reduction in viability.

6. Composted onion waste incorporated into peat soil at a rate of 50% gives good control of *Allium* white rot in pots. The effect of this waste incorporation on disease control in silt and sandy loam soils is inconclusive at the moment due to the low levels of disease recorded in control treatments. These experiments will be repeated to try to improve the uniformity of disease in the different soil types.

7. No unpleasant odours and minimal run-off are produced during composting of vegetable waste (bulb onion, salad onion and sweetcorn + broccoli) mixtures, prepared to defined moisture contents, at 50 ºC for 7 days in bulk tunnels.

8. Results from two field trials suggest that 2 months (Autumn) exposure of sclerotia to composted onion waste (50% incorporation rate) is not sufficient to reduce sclerotia viability under field conditions.