

Optimised compost management for productivity and soil health

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²Lost Gardens of Heligan

³Prideaux Walled Garden



Introduction

Composting is a cornerstone of sustainable land management, transforming organic waste into a nutrient-rich soil amendment that enhances both chemical and physical soil properties. For farmers and horticulturists, the primary value lies in the improvement of soil structure and moisture retention; compost increases the soil's cation exchange capacity (CEC), allowing it to better hold and transition nutrients to plant roots. Furthermore, by introducing beneficial microbial life, compost suppresses soil-borne pathogens and reduces the reliance on synthetic fertilizers, which can lead to significant cost savings and a lower environmental footprint.

The value of compost in agricultural and horticultural systems is fundamentally driven by its microbial ecology, which facilitates the transformation of heterogeneous organic waste into stabilized humic substances. During the thermophilic phase of composting, a succession of aerobic microorganisms, primarily bacteria and actinomycetes, catabolize complex organic polymers through enzymatic hydrolysis (e.g. Pascual et al, 2000). This process not only mineralizes essential macronutrients but also generates metabolic heat sufficient to eliminate most enteric pathogens and weed seeds, effectively "sanitizing" the organic stream.

From a phyto-pathological perspective, mature compost serves as a medium for biological control through several distinct mechanisms. Competitive exclusion is where high populations of beneficial microbes, such as *Bacillus* and *Pseudomonas* species, occupy niche spaces in the rhizosphere, depriving soil-borne pathogens like *Phytophthora* and *Rhizoctonia* of carbon sources and physical attachment sites. Secondly, specific compost-dwelling fungi and bacteria synthesize secondary metabolites (natural antibiotics and volatile organic compounds) that directly inhibit the growth of pathogenic organisms. Finally, interactions between plant roots and non-pathogenic microbes can trigger a physiological "priming" effect, up regulating the plant's own defence genes and increasing its resilience to future biotic stress (Hoitnik & Boehm, 1999).

The role of composting for a grower may well just a means to process waste material containing 'contaminants' such as weed seeds and plant pathogens. Additionally, compost may be used for the addition of nutrients or as a soil conditioner. This project focuses on two aspects of composting. At The Lost Gardens of Heligan in Cornwall, the organic waste from the ornamental garden and the kitchen garden were segregated in order to avoid any potential re-introduction of weed seeds, weed propagules or plant pathogens. This separate composting took more time and space and could result in limited compost availability for some areas of the garden at some times of the year. Therefore, the first part of this project aimed to test whether potential pathogens and invasive weeds could be eliminated in the composting process.

In contrast, at Prideaux Gardens in Cornwall, the highly invasive and persistent bind weed (*Convolvulus sepium*) was well established in some areas of the walled garden. Bindweed is favoured by soils that are well drained, compacted and low in organic matter and a "reflector of an improper decay of organic matter and excessive accumulation of heavy soil metals" (Walters, 1996; McCaman, 2013). In part 2 of the project, an integrated approach was tested to determine whether enhanced soil structure, using compost, broad forking and cover crops could improve soil health and thereby restrict the growth of bind weed.

Method

Compost trial at Lost Gardens of Heligan.

Ten bait bags were prepared to test the impact of composting on disease and weed propagule viability. Each contained bag: 5 leaf strips from the active disease margin of R57 Rhododendron (see below); 20 parsnip seeds 'Tender & True'; 20 dock seeds from a plant in the field margin; 5 oxalis bulbils from Heligan; 5 bind weed root pieces from Heligan; an iButton; and a 2p coin. The contents of the bait bag were held within a nylon bag, sealed with a nylon string, and further tied with a red ribbon, to enhance visibility (Figure 1). The 2p coin was added to assist finding the bait bag at the end of the experiment using a metal detector.

A range of leaf samples for specific Rhododendron plants with suspected *Phytophthora spp* infection were sent to FERA for identification. Plant R57 was selected to be the source of diseased plant material for bait bags. Infected leaves from plant 57 were taken which had an active disease margin. They were surface sterilised using alcohol gel and 50 leaf strips were cut, 5 per bait bag.



Figure 1: *Phytophthora spp* infected leaf strips of Rhododendron R57 (image 1), bait bag contents (image 2), and complete bait bags (image 3).

A range of controls were set up to confirm that the contents of the bait bags were viable. Control treatments were: two trays of seeding compost each containing 25 bindweed root pieces kept at ambient temperature; 200 dock seeds sown into compost and kept at ambient temperature; 200 parsnip 'Tender and True' seeds sown into compost and kept at ambient temperature; 50 oxalis bulbils sown into compost and kept at ambient temperature; R57 leaf strips kept on moist compost at ambient conditions; one pot each of R57 strips, bind weed (50 pieces), dock seeds (200 seeds), parsnip seeds (200 seeds), 50 oxalis bulbils each placed/sown into moist compost and kept in sealed bags in temperatures ~4C. Parsnip seeds which are a similar size to dock seeds were used because the germination of docks could be erratic, as opposed to the parsnip which is bred for uniform and more rapid germination. It was assumed that if parsnips seeds failed to germinate they were likely to have been killed; poor germination in docks may have been due to dormancy or through heat-kill by the compost.

The ten bait bags were dispersed within one compost bay on the 1st April 2023. Just prior to each compost turn the temperature was measured in each bottom and top corner of the exposed face, and in the centre of the compost using a compost temperature probe. On each occasion, the turning was completed into an empty bay using a set procedure such that compost on the edge of the bay

was turned into the centre, and compost in the centre was moved to the outer areas of the bay. In such a way, the aim was to ultimately ensure all compost was heated to the maximum possible temperature. Compost was turned on the same day each week until the 22nd of June 2023, and then again on the 10th and the 19th August. Bait bags were found and removed as compost was used within the compost bay from the 19th August to the 3rd September.

The contents of the bait bags were retrieved. Any weed propagule or seeds were sown to test viability and diseases plant material was sent to FERA to determine whether any diseased plant material from plant R57 was present.

Controls were checked on the first on May, germinated seeds and propagules were counted and discarded. Any remaining seeds and propagules were left until the 3rd September and then checked and counted.

Compost trial at Prideaux Gardens

The compost trial at Prideaux gardens was carried out for two years. The trial design varied between the two years.

In 2023, an area of heavy bind weed infestation was marked out with an approximate area of 3 x 4m. All surface plant material was removed without disturbing the soil on the 9th May 2024. The treatment combinations were compost x broad forked x foliar feed. Trial design is shown in Figure 2. The trial was restricted to one 3 x 5 plot design. Care was taken to ensure that the area had an even infestation of bindweed.

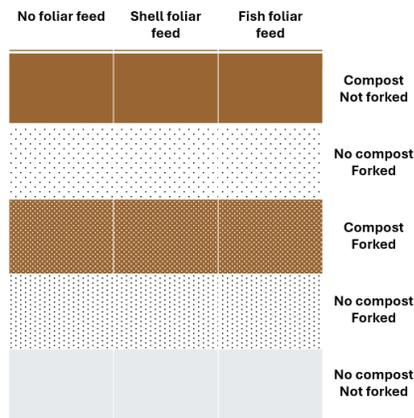


Figure 2: Trial design at Prideaux gardens in year 1 (2024)

The compost addition and broad forking was carried out on the 9th and 10th May 2024. On the 20th May 2024, the trial area was sown to a cover crop mixture of black oats, persian clover, caliente mustard, buckwheat and Mexican marigold. Once full canopy cover was achieved foliar feed applications were carried out on the 17th June (Figure 3). Foliar feed mixtures are detailed in Appendix 1 and 2.

On the 24th June 2024, soil health and bind weed assessments were carried out. Three soil pits were dug per plot (20 x 25 cm) and a VESS score at a depth of 0-15 cm and 20-25cm was recorded per pit. The total number of worms were counted per pit. Single replicates of surface bind weed mass below

ground and above ground, as well as above ground material from other plant species was recorded per plot in an area of 415cm².

The trial area was mown on the 24th June 2024, and covered with tarpaulin until the 21st August. The mass of bind weed roots was recorded from three soil pits per plot (20x 25cm) carefully avoiding previously disturbed areas.

In 2025, an area was covered with plastic sheeting on the 10th April. The surface vegetation was removed from the trial area on the 14th May. Five replicate soil pits of approximate spade dimensions 25cm x 25 cm x 25cm were dug across the trial area. Each pit was assessed for VESS structure in the top 0-10cm and at a depth of 15-25cm, the number of worms were counted and the time for 100ml of water to percolate was recorded.

The trial design was simplified, compared to 2024, with five randomly distributed replicates of compost with broadforking compared to control (no compost or broadfork). In 2023, a standard gardening fork was used to lift the soil profile acting like an agricultural ‘lifter’ soil was not turned the only purpose was to break the mild surface compaction. In 2023 this was labelled ‘fork’. In 2024, Emma Restorick purchased a broadfork which is more efficient to use but achieves the similar action as the previous year, in 2024 these plots were labelled ‘broadfork’. For trial purposes ‘fork’ and ‘broadfork’ achieved the same goal of reducing surface compaction and are therefore not differentiated in the analyses.

Each plot was approximately 1 square metre (Figure 3). The trial area was sown to cover crop on the 2nd June, as per 2024 (Figure 4). The cover crop was destroyed by mowing on the 14th July and left covered with black plastic until 11th August.

Three replicate samples of all plant material were taken per plot of an area of 415cm² and the total dead and live bind weeds roots extracted and weighed. Soil samples were taken from each plot for soil organic matter assessment. A minimum of 10, 30cm depth augered holes were bulked per plot and 1 bulk density sample was taken per plot. Three pits were dug per plot, and the VESS scores, worm counts and the time for infiltration of 100ml of water was assessed.



Figure 3: Ground after being broadforked (image 1) and trial plot layout showing compost over broadforked areas (image 2) at Prideaux Gardens (2025).



Figure 4: Cover crop 1 week prior to mowing and covering (image 1) mown cover crop (image 2)

All statistical analyses was done using Genstat (VSNI, 23rd Edition). All count data was transformed. The soil data in year 2 was analysed using ANOVA. Weed data over the two years was analysed using REML Linear Regression.

Results

Lost Gardens of Heligan

The compost heap at Heligan sustained an average temperature of over 60C for 27 days, which included four successive compost turnings (Figure 5). At the time of bait bag retrieval, the compost heap was an average of 41C after 132 days of composting.

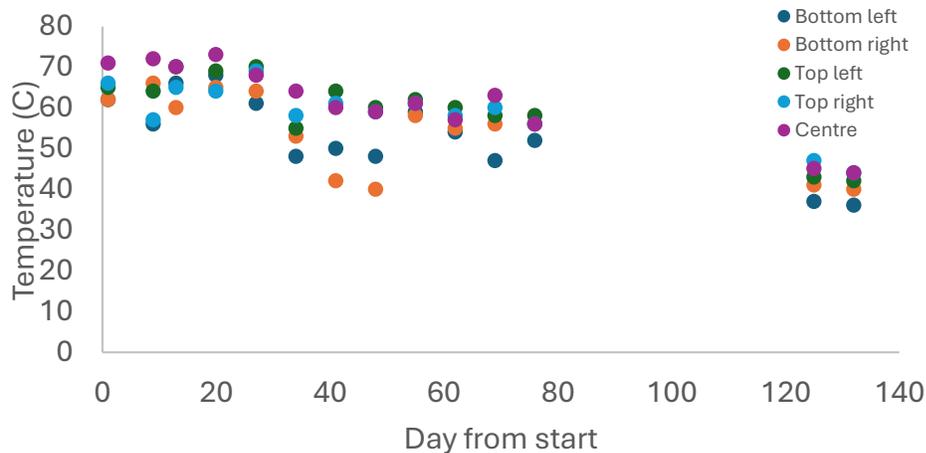


Figure 5: The temperature of the compost pile just prior to turning. On each occasion temperature was measured at the bottom left, bottom right, top left, top right and centre using a compost thermometer. The first measurement was taken on the 1st April 2023.

On September 5, 2023, the bait bags were retrieved for analysis. At that time, the bag contents had completely decomposed into "dust," with no recognizable weeds or seeds remaining. Six samples were sent to FERA to test for *Phytophthora*; all results were negative.

To ensure the experiment's validity, control samples were monitored to confirm the initial viability of the seeds and weeds. On the 1st May, 42 out of 50 ambient bindweed samples were shooting, five remained dormant, and three had rotted. One bindweed root had produced a shoot from the fridge control, while the others remained dormant. Oxalis, dock, and parsnip showed no initial activity in May. A significant number of parsnip seeds in the cold treatment had germinated by September 3. The successful growth in the control groups confirms that the bindweed and parsnip seeds were viable at the start of the study. However, because the bait bags contained no intact weeds or seeds upon retrieval, it is concluded that the composting process effectively destroyed all propagules.

Prideaux Gardens

Pre-trial soil assessments

In 2024, there was evidence of some surface compaction prior to the trial (Figure 6). In 2025, this was quantified, with a visual evaluation of soil structure score of between 2 and 3 on the surface across the trial plot indicating some compaction (Table 1). There was no compaction at depth. Average worm counts were 3, but this varied across the plot. Infiltration times for 100ml of water averaged 3 minutes 20 seconds which were within the normal expected range.



Figure 6: Trial area in 2024 before (image 1) and after surface clearance of weeds (image 2) and indication of mild surface compaction (image 3)

Post-trial soil assessments

In year 2024, there was a single replicate per treatment therefore no results can statistically analysed for significance. Early indications suggested that the broadfork/dig may have reduced surface compaction (Figure 7) in all but the fish foliar treatment. There was no compaction at 20cm depth. The application of compost is likely to have increased worm numbers, probably from brandling worms introduced upon compost application (Figure 8).

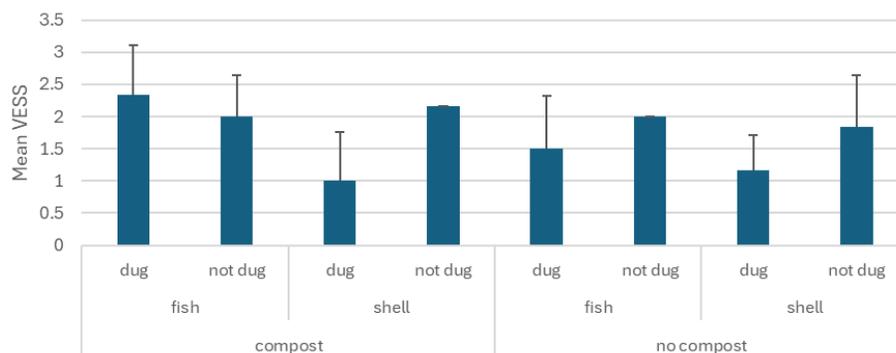


Figure 7: Average top (0-15cm depth) Visual Evaluation of Soil Structure with error bars representing standard error between sub-replicates.

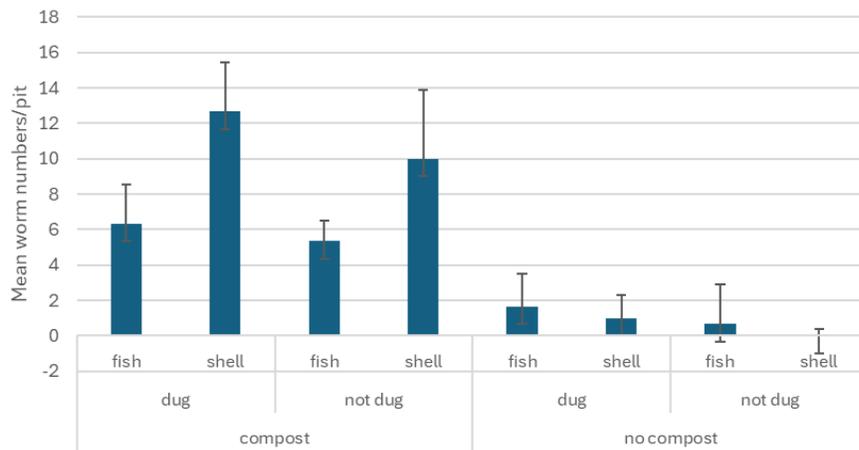


Figure 8: Mean worm counts across trial plots. Error bars indicate standard error between sub-replicates.

In 2025, trial plots were fully randomised, the mean VESS (0-15cm) was 2.0 for control plots and 1.5 for treated plots but results were not significantly different ($P=0.075$). There was no difference in control and treated VESS (15-15cm) with means ranging from 1 to 1.03. There was no significant difference in worm numbers, conditions were very dry at the time of assessments with mean number of worm per soil pit for control and treated plots ranging from 0.80 and 0.87.

Table 1: Soil structure (VESS) worm count and water infiltration time across the trial plot area in 2025 at trial initiation.

Replicate	VESS score (top 0-15cm)	VESS score (bottom 15-25cm)	Worm count	Infiltration time for 100ml water (seconds)
1	2	1	5	79
2	2	1	11	45
3	3	1	0	301
4	3	1	0	88
5	3	1	1	69

If data from the two years is analysed together, the compost plus broadforking (and ignoring foliar feed) significantly improved the surface VESS score in the treated plots ($P=0.017$), but there is no effect on lower soil structure ($P=0.170$). Worm count was significantly improved in the treated compared to control plots ($P = 0.048$).

Bind weed assessments

2024, year 1

Treatments were in single replicates in 2024, therefore no clear statements can be made about project findings. Nevertheless, data suggests (Figure 9) that bind weed below ground mass may be lower in plots that had been dug with a broad fork and had compost application even prior to cover crop destruction in June. From single data point measurements of above ground biomass early data

indicates that compost treatment disproportionately favoured other species compared to bind weed (Figure 10).

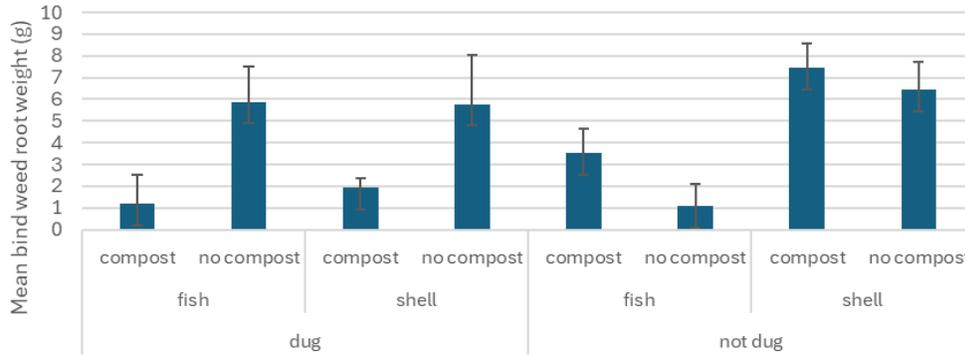


Figure 9: Mean bind weed root mass per treatment in June prior to mowing of cover crop, error bars represent standard error.

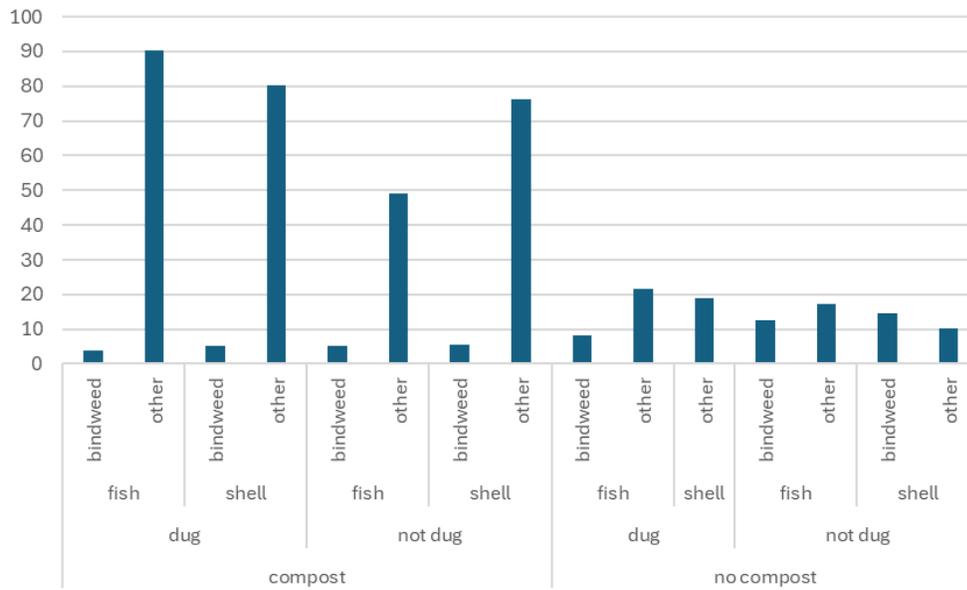


Figure 10: Total aboveground plant mass (g) across treatments for bind weed and for other plant species. Assessments were carried out in June 2024, prior to cover crop destruction

The cover crops were mown and plots covered until August 2024. The mass of bind weed per plot was recorded per plot. Again, although single treatments replicate prohibits statistical analysis, early data suggested that a combination of digging and composting reduced bind weed root mass (Figure 11). There was no clear effect of the different foliar treatments.

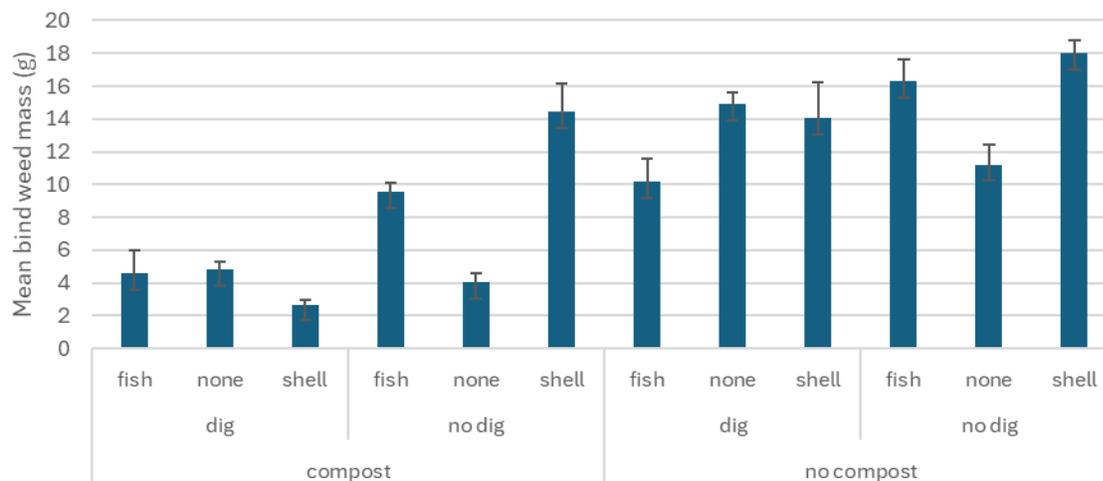


Figure 11: Mean bind weed root mass, error bars represent standard error of sub replicates within plots.

2025, year 2

The project design in year 2 allowed for statistical analysis of the results. The assessment of bind weed was carried out in August after cover crop destruction and plot covering. The trial area in year 2025 had a lower infestation of bind weed than the trial area in year 2024. In this year, there was no significant reduction in alive or dead bind weed following the compost and broad fork treatment compared to the control ($P = 0.553$ and $P=0.774$ respectively).

Bindweed data, two years

The final August bindweed mass data from year 2024 was analysed with 2025 data. Of the 2024 data, only the results for control (no broadfork, no compost) and treated (broadfork and compost) were used and the effect of foliar feed was ignored and therefore added to statistical error. Over the two years there was a significant reduction ($P<0.001$) in bind weed as a consequence of compost and broadfork with over a halving of the total bind weed root mass (mean treated = 3.6g/sample area compared to control = 8.1g/sample area)

Soil carbon data 2025

The mean soil organic matter was greater in the treated compared to the control plots (Table 2) but the difference was not significant ($P=0.607$). Soil carbon was higher in the control plots, a consequence of the higher soil density, but the difference between treatments was not significant.

Table 2: Mean soil organic matter and mean carbon for Prideaux Gardens trial in 2025. Figures in brackets indicate the standard error.

	Soil organic matter (%)	Carbon (t/ha equivalent)
Compost & broadfork	10.74 (0.83)	163.5 (12.70)
Control	10.2 (0.34)	172.5 (8.56)

Conclusion

The results from the trials at the Lost Gardens of Heligan and Prideaux Gardens demonstrate that integrated compost management, specifically high-temperature composting and broadforking to ease surface compaction with compost, is an effective strategy for neutralizing invasive propagules and significantly improving soil health. At Heligan, the composting process maintained an average temperature exceeding 60°C for 27 days, a thermal duration sufficient to completely decompose bait bag contents into "dust." Although control groups confirmed that bindweed and parsnip seeds were initially viable, no intact propagules remained after the composting cycle, and FERA analysis verified the absence of *Phytophthora*. This confirms that the Heligan composting protocol is a reliable method for sanitizing garden waste and preventing the reintroduction of pathogens and weeds.

At Prideaux Gardens, the transition from initial observations in 2024 to randomized trials in 2025 provided clear statistical evidence of the impact of improved soil health on reducing bind weed infestation. The combination of compost application and broadforking significantly improved surface soil structure effectively reducing surface compaction.

The longitudinal analysis of bindweed suppression over two years further highlights the cumulative benefits of these interventions. While single-year results varied, the combined data from 2024 and 2025 confirms a significant reduction in bindweed root mass. On average, the total root mass in treated areas was more than halved. Furthermore, early data indicates that compost application may disproportionately favour the growth of other plant species, potentially allowing desirable vegetation to outcompete bindweed in a garden setting.

Ultimately, the study concludes that a management regime of broadforking and compost application is highly effective for the long-term control of bindweed and the enhancement of topsoil quality. These findings provide a verified framework for gardeners to recycle organic matter safely while simultaneously improving the biological and physical health of the land.

Acknowledgement

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Appendix 1

Images of plots after tarpaulin removal in August 2024. All treatments had cover crop on them, but it is only evident where compost was also added. The extent of bindweed growth under the plastic is clear where compost is absent.





Appendix 2

Fish foliar feed recipe

The fish guts were approximately 2kg Real mix from Pysk fish. Brown sugar was Demerara sugar.

Feed was diluted to 60ml per 10 litres of water. Two watering cans were used to cover 3 x 6m width

Fish Amino Acid (FAA)
10 litre bucket with a lid
Brown sugar
Fish guts, bones and heads

NITROGEN



- ① Add a thin layer of sugar to the bucket until you can not see the bottom
- ② Layer the fish on top 3 inches thick
- ③ Now layer 3 inches of sugar on top
- ④ Repeat until jar is $\frac{3}{4}$ full
- always finish on a sugar layer
- ⑤ Sprinkle 1M03 on the top layer if available
- ⑥ Find a weight that fits on top of the sugar + fish layers. Seal with lid.
- ⑦ Leave for 3 months to ferment
- ⑧ If at any point it starts to smell bad, add more sugar.



Thin layer sugar to start

Appendix 3

Shell recipe

Approximately 1kg of eggs shells roasted in the oven and crushed immersed in 5 litres of apple cider vinegar with the mother. This was left to ferment for at least 3 weeks before decanting.

This was diluted at 20ml per 10 litres. Two watering cans were used to cover 3 x 6m width