Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
June 2005
Advanced Level Examination

ENVIRONMENTAL SCIENCE ESC7
Unit 7 Alternative to Practical Investigation

Wednesday 29 June 2005 1.30 pm to 3.30 pm

No additional materials are required.
You may use a calculator.

Time allowed: 2 hours

Instructions
- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions in the spaces provided.
- Do all rough work in this book. Cross through any work you do not want marked.

Information
- The maximum mark for this paper is 75.
- Mark allocations are shown in brackets.
- You are expected to use a calculator where appropriate.
- You will be assessed on your ability to use an appropriate form and style of writing, to organise relevant information clearly and coherently, and to use specialist vocabulary, where appropriate.
- The degree of legibility of your handwriting and the level of accuracy of your spelling, punctuation and grammar will also be taken into account.
- This unit assesses your understanding of the relationship between the different aspects of Environmental Science.

For Examiner's Use			
Number	Mark	Number	Mark
1			
2			
3			
4			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

AN INVESTIGATION INTO THE DECOMPOSITION OF ORGANIC MATERIAL AND THE VALUE OF COMPOSTING

Aim

A group of Advanced Level Environmental Science students decided to investigate the decomposition of organic material and the importance of compost for plant growth.

The students carried out their research in local fields and in the laboratory.

The students decided to investigate:

- the effect of garden chemicals (herbicides/insecticides/fungicides) on the rate of decomposition of plant material;
- the effect of the addition of compost on the population sizes of species of soil invertebrates;
- the effectiveness of compost made from garden waste as an alternative to peat for plant growth.

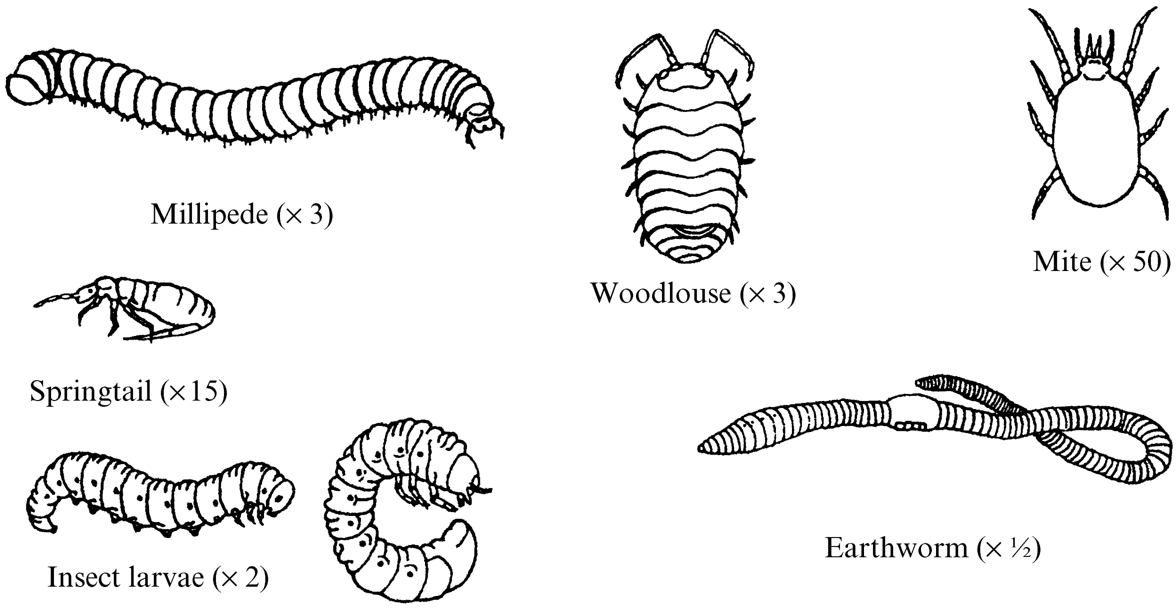
Background Information

Soil organisms

(a) Detritivores

The soil is home to a variety of macro-invertebrates including millipedes, woodlice, mites, springtails and insect larvae as well as earthworms. Many of these organisms feed on detritus i.e. partly decomposed organic material. They accelerate the process of decay by shredding the organic material, thereby increasing the surface area accessible to attack by micro-organisms (decomposers). Detritivores also transport material through the soil creating spaces and passages which improve the drainage and aeration of the soil.

Detritivores exist in large numbers in temperate, terrestrial ecosystems where the soil is moist and rich in organic matter. In most environments, the most abundant soil dwellers are springtails which exist in populations of tens of thousands per square metre in many agricultural soils.



Source: The Nuffield Foundation. *Key to small organisms in soil, litter and water troughs* (Longmans, Green and Co Ltd) 1966

(b) Decomposers

While earthworms and other soil invertebrates are important in transforming detritus into humus, bacteria and fungi are the main decomposers in the later stages of humification of organic matter. These micro-organisms are essential for the recycling of nutrients. Especially important are those that can secrete the enzymes necessary to break down cellulose and woody tissues of plants. Bacteria and fungi exist in the soil in enormous numbers. Bacteria, although extremely small with several million per gram of soil, have a live weight of 1000–6000 kg per hectare.

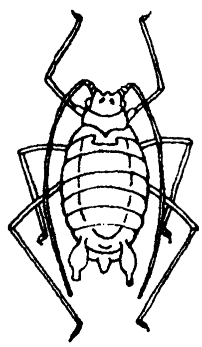
Commonly used garden chemicals

(a) Herbicides kill weeds. Many act as systemic herbicides, which are absorbed through the roots of plants and transported throughout the plant and which prevent further growth by inhibiting cell division or photosynthesis. As these are organic compounds, they can be used as food by soil micro-organisms, increasing their populations. Herbicides tend to have low toxicity for earthworms but can cause population reductions by decreasing organic matter input and cover from weed plants.

(b) Fungicides are used to kill the fungi that cause leaf spot, mildews, rusts, scab and other fungal diseases. These fungi are parasitic types only infecting living tissue. However, fungicides will also affect the fungi involved in the decomposition of organic matter and tend to be very toxic to earthworms.

(c) Insecticides are used to kill insect pests such as wireworms, leather jackets, ants and aphids. If they contaminate the soil, they also kill springtails, millipedes and other soil arthropods that are important detritivores.

Wireworm (× 3)



Soil aphid (× 6)

Leatherjacket (× 1)

Source: The Nuffield Foundation. *Key to small organisms in soil, litter and water troughs* (Longmans, Green and Co Ltd) 1966

Importance of Peat bogs

Peat bogs are among the most ancient and threatened of Britain's ecosystems containing a highly specialised flora including many rare species. Peat is made of incompletely decomposed plant remains, mainly sedges, grasses, reeds and mosses. It forms when the natural processes of decay are halted by waterlogging and the consequent exclusion of oxygen. In these conditions, the remains of wetland plants become compacted to form peat. The formation of peat is a very slow process with an average growth rate of no more than 1 mm per year.

Over time, the peat increases in thickness, retaining most of the nutrients. Therefore the only nutrients available for plant growth are those dissolved in rain. These extreme conditions mean that few plants can survive without special means of obtaining nutrients. The most successful plant is the bog moss, *Sphagnum*, which dominates the bog flora creating an acid environment.

Peat has traditionally been used in horticulture because of its unique characteristics of water retention, porosity, stability and nutrient content. Peat extraction is taking place on a commercial scale as a source of compost for horticultural use and it is estimated that 95% of our peatlands have now been destroyed by this and other developments.

Once peat is extracted, oxygen enters and the partly decayed vegetation can continue to be broken down releasing nutrients which can be used by plants for growth.

Composting

Environmentalists argue that peat as a growing medium for plants could be replaced by locally produced waste-derived composts. This would not only reduce the amount of peat extracted from peat bogs but would also recycle large amounts of waste which would otherwise have gone to landfill.

Making compost involves setting up ideal conditions for the bacteria, fungi and invertebrates involved in the decomposition process. These organisms thrive in a moist, but not waterlogged environment, which is well aerated. Given these conditions, colonies of bacteria can double their numbers every hour, reaching huge numbers. Micro-organisms respire, consume and reproduce, converting energy stored in organic materials into heat and releasing nutrients for plant growth.

Any organic material can be composted but some kitchen waste, such as meat and fish, is less suitable. The best materials to compost are materials such as fruit and vegetable trimmings, weeds, grass cuttings, hay and straw, hedge trimmings, paper, tissues, egg boxes, tea leaves, wood chippings and cardboard packaging. At cool temperatures the compost is ready to use after six months to one year but at high temperatures the process is much quicker.

NO QUESTIONS APPEAR ON THIS PAGE

TURN OVER FOR QUESTION 1

This investigation is in **two** *sections.*
Section A *is in* **three** *parts and tests the skills of planning, implementing, analysing and drawing conclusions.*
Section B *tests the ability to discuss the findings and evaluate the whole investigation.*

SECTION A

Answer **all** questions in the spaces provided.

1 Effect of garden chemicals on the rate of decomposition of plant material

In October 2002, equal numbers of discs cut from the leaves of sweet chestnut trees were placed in four nylon bags of known weight. The filled bags were weighed and then buried in the centres of four 1 m^2 plots of rich garden soil where no pesticides had been used for at least five years.

(a) (i) Suggest why nylon bags were chosen for the burial of leaf discs rather than bags made of either cotton or linen.

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(2 marks)

(ii) Four different mesh sizes for the nylon bags were available for use in the investigation. The organisms able to enter mesh of each size are shown in **Table 1**.

Mesh size / mm	Organisms
7	All micro-organisms and soil invertebrates
1	All micro-organisms and soil invertebrates with the exception of larger worms
0.5	All micro-organisms and very small soil invertebrates only
0.003	Micro-organisms only

Table 1

Suggest the most appropriate mesh size to use in this investigation. Give a reason for your answer.

Mesh size ....

Reason for choice ....

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(2 marks)

(b) Other than the type and mass of plant material used, suggest **three** factors that need to be kept constant in order for the investigation to be a fair test.

1. ....

2. ....

3. ....

(3 marks)

(c) The control plot (plot **A**) was left untouched but plots **B, C** and **D** were watered weekly with 5 litres of water to which different garden chemicals had been added as shown in **Table 2**.

Plot	Liquid added weekly to each 1 m^2 plot
B	Water with herbicide added
C	Water with fungicide added
D	Water with insecticide added

Table 2

Garden chemicals can be harmful to humans if swallowed, inhaled or absorbed through the skin. Suggest **two** precautions that should be taken to prevent chemicals from entering the human body.

1. ....

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2. ....

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(2 marks)

QUESTION 1 CONTINUES ON THE NEXT PAGE

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(d) The leaf discs were dug up at six monthly intervals for the first 18 months of the study. The discs were then re-weighed. The results for plot **C** are shown in **Table 3**.

	Original mass in October 2002 / g	**April 2003**	**October 2003**	**April 2004**
Mass of leaf tissue remaining in plot **C** / g	15.0	9.0	7.8	6.3

Table 3

The percentage of leaf mass remaining in the experimental plots is shown in **Table 4**.

	Percentage of leaf mass remaining			
Plot	**October 2002**	**April 2003**	**October 2003**	**April 2004**
A control	100	36	20	12
B with herbicide	100	49	42	29
C with fungicide	100			
D with insecticide	100	65	56	39

Table 4

(i) Complete **Table 4** by calculating the percentage leaf mass remaining for each six monthly interval for plot **C**.

Show your working.

(2 marks)

(ii) Explain why the percentage leaf mass remaining is used rather than the total mass.

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(1 mark)

(iii) On the graph paper, plot a graph of the results shown in the completed **Table 4**.

(4 marks)

16

TURN OVER FOR THE NEXT QUESTION

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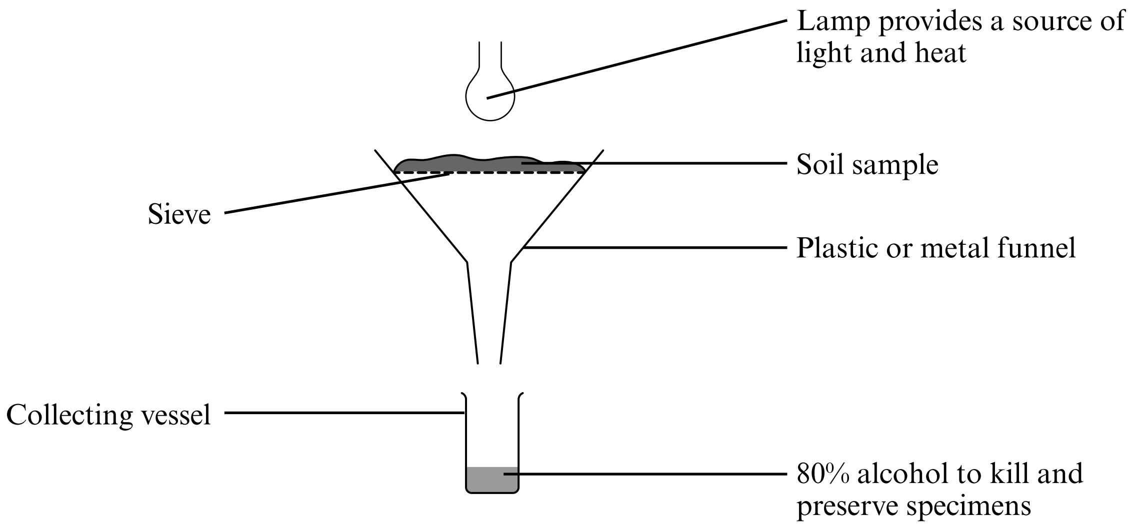
2 Investigation of soil invertebrate populations in soils treated with garden waste-derived compost compared to untreated soils

(a) An investigation into the effect of adding compost to garden soil was carried out in two further 1 m^2 plots. One plot had a large quantity of compost dug into the soil in the autumn; the second plot was untreated. The following spring, six soil samples were taken at random from each plot and Tüllgren funnels were set up to extract the invertebrates. The diagram shows a Tüllgren funnel used for this part of the investigation.



(i) Describe how the Tüllgren funnel extracts soil organisms.

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(2 marks)

(ii) Describe an appropriate method for choosing the sites for soil sampling in each of the experimental plots.

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(2 marks)

Turn over ►

(b) After 24 hours the total number of invertebrates extracted by each of the Tüllgren funnels was counted. The results are shown in **Table 5**.

	Total number of invertebrates collected in sample numbers					
	1	**2**	**3**	**4**	**5**	**6**
Garden soil	12	8	6	7	11	10
Garden soil with added compost	10	13	18	9	12	15

Table 5

(i) State a hypothesis suggested by these results.

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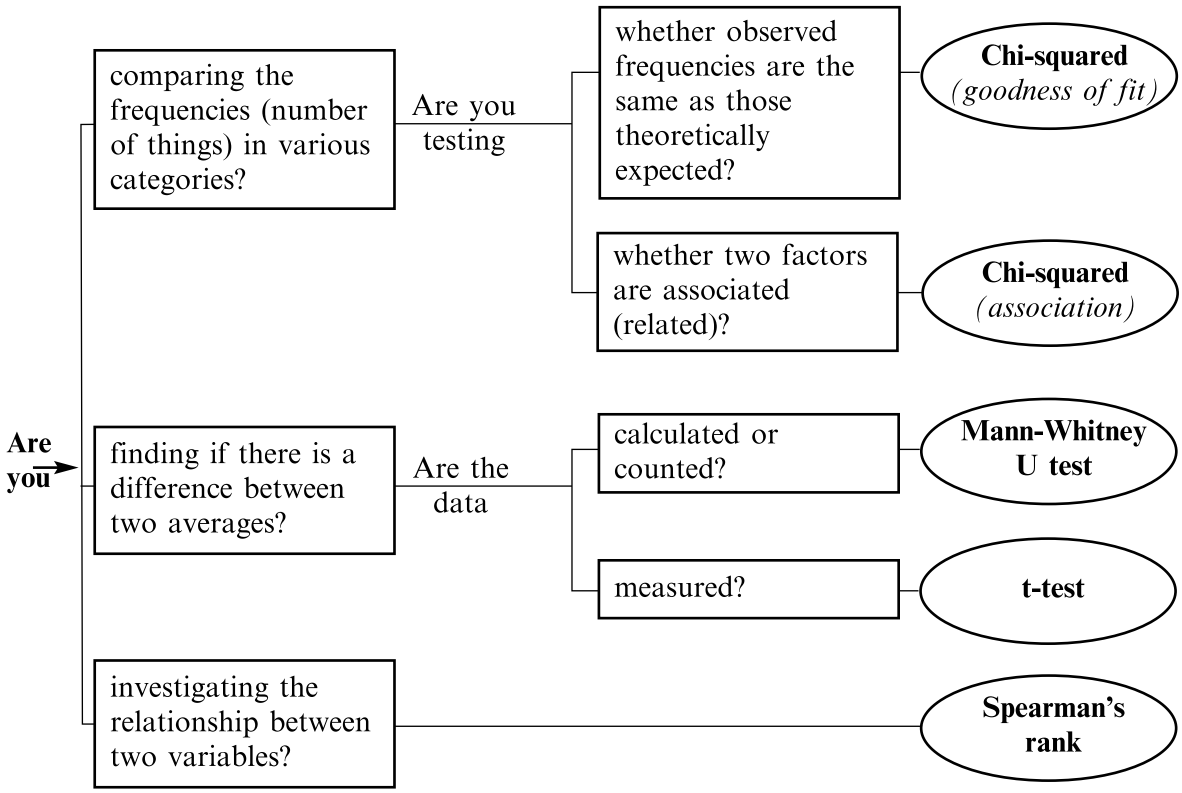
(1 mark)

(ii) Use the flow diagram to choose an appropriate statistical technique to test your hypothesis. Give **two** reasons to justify your choice of test.



Choice of statistical test

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Reasons for choice

1. ....

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2. ....

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(3 marks)

(iii) Carry out your chosen test using the data in **Table 5** and information in the Appendix.

Show your working.

(6 marks)

QUESTION 2 CONTINUES ON THE NEXT PAGE

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(iv) State your conclusion clearly.

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(1 mark)

(v) The critical value used for many statistical tests is often at the $p = 0.05$ level. Explain the meaning of this level of significance.

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(1 mark)

16

3 Investigation into the effect of garden compost and peat on plant growth and soil properties

(a) A laboratory experiment was set up to test the hypothesis that compost made from garden waste is as effective a growth medium for plants as commercially available peat-based compost.

Two large plastic horticultural seed trays were filled with each of the growing media:

Tray **Y** with garden compost;
Tray **Z** with commercially produced peat-based compost.

50 radish seeds were sown in each tray and the two trays were placed in suitable conditions to allow the seeds to germinate.

(i) Suggest why radish was an appropriate plant to use in this experiment.

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(1 mark)

(ii) State **three** variables which would need to be kept constant in this experiment.

1. ....

2. ....

3. ....
(3 marks)

Three days after germination, five seedlings from each tray were selected at random and removed. The seedlings were gently rinsed under running water to remove any of the growing medium. The growth of the seedlings was then recorded by measuring dry mass and the mean seedling dry mass was calculated. Every three days, a further five seedlings from each tray were removed and their dry mass measured. The experiment was terminated after 18 days.

(iii) Explain why dry mass was used as a measure of growth rather than fresh mass.

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(1 mark)

QUESTION 3 CONTINUES ON THE NEXT PAGE

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(iv) Explain why five seedlings were used on each occasion.

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(1 mark)

(v) Describe how the dry mass of the seedlings would have been measured.

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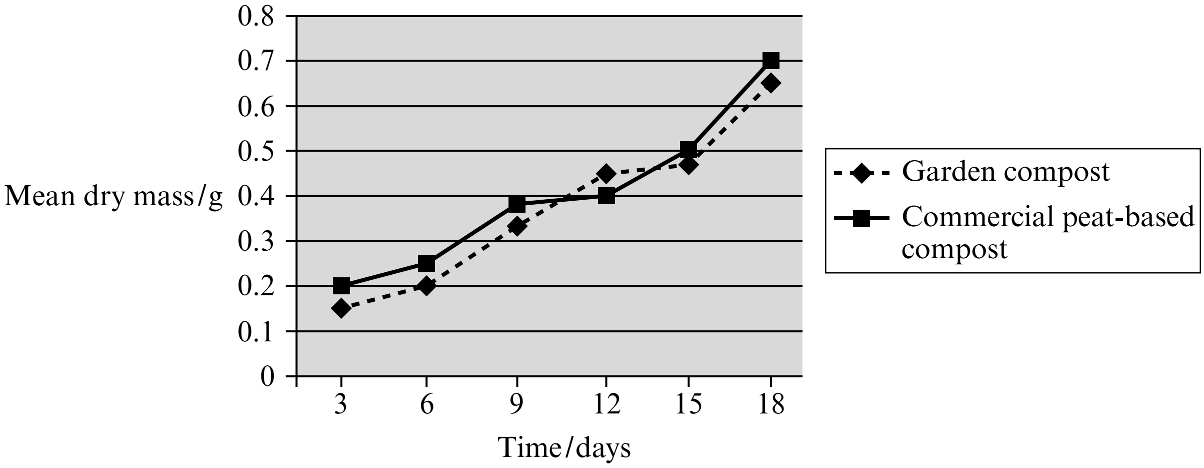
(3 marks)

(b) The mean dry mass of the seedlings is shown in the graph.



(i) State **two** characteristics of the growing media that should be measured to explain the trends shown by the results.

1. ....

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2. ....

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(2 marks)

(ii) Describe the method used to measure **one** of these characteristics.

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(3 marks)

14

TURN OVER FOR THE NEXT QUESTION

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SECTION B

Answer **all** parts of the question in the spaces provided.

In order to gain credit in this section your answer should be written in continuous prose and expressed logically and in clear scientific terms.

4 (a) Using your own knowledge, information in the background section and with reference to the investigations carried out, discuss:

(i) the rate of decomposition of plant material; (*Question 1, page 6*)

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(7 marks)

(ii) the effect of increased organic matter on soil animals; (*Question 2, page 11*)

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(3 marks)

(iii) the effectiveness of garden waste-derived compost as an alternative to peat for plant growth. (*Question 3, page 15*)

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(3 marks)

QUESTION 4 CONTINUES ON THE NEXT PAGE

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(b) Discuss any factors relating to the methods used in all parts of the investigation that might affect the reliability of the results obtained.

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(5 marks)

(c) (i) Suggest how the techniques or procedures used in the three parts of the investigation might be modified.

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(3 marks)

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(ii) How could this investigation be extended to test further the original aims?

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(3 marks)

(d) Suggest how environmental scientists might use the results of this study to advise gardeners, horticulturalists and government bodies on good environmental practice.

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(5 marks)

29

END OF QUESTIONS

TURN OVER FOR APPENDIX

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APPENDIX

Statistical formulae and tables

1 Mean

$$\bar{x} = \frac{\sum x}{n}$$

where:
$\bar{x}$ = mean
x = the individual measurements
n = total number of measurements
$\sum$ = the sum of

2 Standard deviation(s)

$$s = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}}$$

3 Chi-squared (χ^2) test

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

where:
$\sum$ = the sum of
O = the observed value
E = the expected value

Critical Values for the Chi-Square (χ^2) Test

Degrees of Freedom (df)	**Level of significance (p)**				
	0.05	0.025	0.01	0.005	0.001
1	3.84	5.02	6.63	7.88	10.83
2	5.99	7.38	9.21	10.60	13.81
3	7.81	9.35	11.34	12.84	16.27
4	9.49	11.14	13.28	14.86	18.47
5	11.07	12.83	15.09	16.75	20.52
6	12.59	14.45	16.81	18.55	22.46
7	14.07	16.01	18.48	20.28	24.32
8	15.51	17.53	20.09	21.96	26.13
9	16.92	19.02	21.67	23.59	27.88
10	18.31	20.48	23.21	25.19	29.59
11	19.68	21.92	24.73	26.76	31.26
12	21.03	23.34	26.22	28.30	32.91
13	22.36	24.74	27.69	29.82	34.53
14	23.68	26.12	29.14	31.32	36.12

4 Mann-Whitney U Test

$$U = n_1 n_2 + \frac{n_1(n_1 + 1)}{2} - R_1$$

$$U' = n_1 n_2 + \frac{n_2(n_2 + 1)}{2} - R_2$$

where:
R_1 = sum of the ranks of sample 1
R_2 = sum of the ranks of sample 2
n_1 = size of the smaller sample
n_2 = size of the larger sample

Critical values for the Mann-Whitney U test (at the p = 0.05 level). If the smallest U value is less than or equal to the critical value then there is a significant difference between the two sets of data.

	Values of n_2																			
Values of n_1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1																				
2								0	0	0	0	1	1	1	1	1	2	2	2	2
3					0	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8
4				0	1	2	3	4	4	5	6	7	8	9	10	11	11	12	13	13
5			0	1	2	3	5	6	7	8	9	11	12	13	14	15	17	18	19	20
6			1	2	3	5	6	8	10	11	13	14	16	17	19	21	22	24	25	27
7			1	3	5	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
8		0	2	4	6	8	10	13	15	17	19	22	24	26	29	31	34	36	38	41
9		0	2	4	7	10	12	15	17	20	23	26	28	31	34	37	39	42	45	48
10		0	3	5	8	11	14	17	20	23	26	29	33	36	39	42	45	48	52	55
11		0	3	6	9	13	16	19	23	26	30	33	37	40	44	47	51	55	58	62
12		1	4	7	11	14	18	22	26	29	33	37	41	45	49	53	57	61	65	69
13		1	4	8	12	16	20	24	28	33	37	41	45	50	54	59	63	67	72	76
14		1	5	9	13	17	22	26	31	36	40	45	50	55	59	64	67	74	78	83
15		1	5	10	14	19	24	29	34	39	44	49	54	59	64	70	75	80	85	90
16		1	6	11	15	21	26	31	37	42	47	53	59	64	70	75	81	86	92	98
17		2	6	11	17	22	28	34	39	45	51	57	63	67	75	81	87	93	99	105
18		2	7	12	18	24	30	36	42	48	55	61	67	74	80	86	93	99	106	112
19		2	7	13	19	25	32	38	45	52	58	65	72	78	85	92	99	106	113	119
20		2	8	13	20	27	34	41	48	55	62	69	76	83	90	98	105	112	119	127

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5 t-test

$$t = \frac{[\bar{x}_1 - \bar{x}_2]}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}} \qquad v = n_1 + n_2 - 2$$

where:
s = standard deviation (candidates should note that on some calculators the symbol σ may appear in place of the symbol s).
$\bar{x}$ = mean
n = sample size
v = degrees of freedom

Degrees of freedom (df)	***p* values**			
	0.10	0.05	0.01	0.001
1	6.31	12.71	63.66	636.60
2	2.92	4.30	9.92	31.60
3	2.35	3.18	5.84	12.92
4	2.13	2.78	4.60	8.61
5	2.02	2.57	4.03	6.37
6	1.94	2.45	3.71	5.96
7	1.89	2.36	3.50	5.41
8	1.86	2.31	3.36	5.04
9	1.83	2.26	3.25	4.78
10	1.81	2.23	3.17	4.59
12	1.78	2.18	3.05	4.32
14	1.76	2.15	2.98	4.14
16	1.75	2.12	2.92	4.02
18	1.73	2.10	2.88	3.92
20	1.72	2.09	2.85	3.85
22	1.72	2.08	2.82	3.79
24	1.71	2.06	2.80	3.74
26	1.71	2.06	2.78	3.71
28	1.70	2.05	2.76	3.67
30	1.70	2.04	2.75	3.65
40	1.68	2.02	2.70	3.55
60	1.67	2.00	2.66	3.46
120	1.66	1.98	2.62	3.37
∝	1.64	1.96	2.58	3.29

6 Spearman Rank Correlation Coefficient (r_s)

$$r_s = 1 - \frac{6 \sum D^2}{n(n^2 - 1)}$$

where:
$\sum$ = the sum of
D = the difference between each pair of ranks
n = sample size

Critical values for the Spearman Rank Correlation (r_s)

Number of pairs of measurements	**Critical value**
5	1.00
6	0.89
7	0.79
8	0.74
9	0.68
10	0.65
12	0.59
14	0.54
16	0.51
18	0.48
20	0.45
22	0.43
24	0.41
26	0.39
28	0.38
30	0.36

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