Welsh Biochar Report

December 2017 Tony Davies

The Welsh Biochar project was funded by Arwain

Funded through the Rural Development Plan for Wales (RDP) as part of the Welsh Government and European Agricultural Fund for Rural Development, Arwain is the LEADER 2014 – 2020 programme in Powys.

Contents

All photographs and tables are the author’s own unless specified.

Acknowledgments

Tom Spicer, Agriculture and Countryside Management Student

1. Introduction

This Arwain funded project was based at Henfron farm in the Elan Valley, mid Wales. This organic tenanted farm is part of the Elan Trust Estate. Tony Davies is leading the project researching options and experimenting with biochar with the main objective of establishing a product to sell in the retail market place. The biochar is produced from a *Molinia caerulea* (Molinia) grass which covers a large expanse of the Cambrian mountains including a significant percentage of Henfron Farm.

1.1 Biochar

Biochar is produced through the process of pyrolysis that heats biomass with limited amounts of oxygen present. Molinia is cooked at temperatures up to 500˚C in an efficient insulated retort. The first stage of pyrolysis is the endothermic stage as external energy (fuel in the firebox) is needed to start the process. After the moisture is evaporated the gas is directed into the firebox and ignited (exothermic stage) ensuring the rest of the process continues without any external fuel inputs. The cellulose and lignin in the biomass breakdown to produce ‘syngas’, which includes: carbon monoxide (CO2), methane (CH4) and hydrogen (H). This gas can either be combusted or captured for energy generation. The resulting Biochar can be as high as 78% carbon as well as having small amounts of Hydrogen, Oxygen, Nitrogen, Sulphur, Phosphorus, Potassium, Calcium and other mineral elements.

Biochar is black, fine grained, extremely porous, lightweight and resists degradation and can lock up carbon in soil for hundreds or thousands of years. Biochar was used to improve the fertility of soils in the Amazon basin at least 2,500 years ago. Biochar was created and incorporated in small plots of land, the soil is named ‘Terra Preta’, Portugese for ‘black earth’.

Molinia Biochar

Although there is strong evidence that biochar does have beneficial effects when added to soils (UK Biochar Research Centre, 2017) there is very little awareness of biochar by gardeners so it is difficult to sell pure biochar. The aim of the first part of this project is to produce a nutrient rich compost which could be mixed with biochar, compost is a product which already purchased in large quantities by gardeners.

Biochar was first produced at Henfron farm with surplus Molinia under a previous Welsh Government funded ‘Nature Fund’ project (Welsh Government, 2013). Molinia biochar produced at Henfron farm has been analysed at The Institute of Biological, Environmental & Rural Sciences (IBERS) and found to be over 70% carbon. The analysis report (Corton, et al., 2015) states: “*Further research is now required to optimise* *its production and identify potential uses and markets for biochar produced from the management of Molinia grassland."*

1.2 Molinia Caerulea

The Cambrian mountains have large areas of Molinia which is a perennial deciduous grass species and mostly grows on damp, acid or peaty soil. Molinia shoots start developing in April or May with the peak in vegetation mass in August. In September the first leaves are dead with the rest dying by November. Livestock do eat Molinia in its early growth but later in the season it becomes unpalatable for sheep although cattle will still graze it. In the autumn it completely sheds its leaves, leaving limited forage for grazing animals during the winter. The build-up of this grass has an impact on species diversity and habitat as well as decreasing the agricultural productivity of the land. Molinia is sometimes named 'Purple Moor Grass' or 'Rhos hay' when harvested.

Molinia on Henfron Farm, September and January

Conservationists are concerned about the species poor landscapes that are a result of Molinia dominance. According to a report commissioned by the Welsh Government: 'Unlocking the Potential of the Uplands' (Welsh Government, 2012) *"The spread of purple moor grass across large parts of upland Wales has had negative effects on agricultural productivity, access and recreation, fire risk and nature conservation."*

Areas of Molinia have decreased in lowland areas due to land improvement but the quantity of Purple Moor Grass has increased in the uplands caused by a lack of grazing according to the (Biological Records Centre, 2012). At the ADAS Pwllpeirion Research Centre, land with limited Purple Moor Grass which has not been grazed for 20 years is now dominated by Molinia (Fraser, 2011). Conservationists are also concerned about the species poor landscapes that are a result of Molinia dominance (Chambers, et al., 1999).

Alongside grazing and harvesting, Molinia was also thought to be controlled historically by burning the excess dead grass in the winter (Gimingham, 1972). Other more recent evidence now explains that burning the dead Molinia during the winter actually encourages its growth (Bryce, et al., 2005).

The Nature Fund biochar project was completed in 2015. The land surveys suggest that removing Molinia from the mountain improves the diversity of the habitat (Lewis & Vincett, 2015).

1.3 Biochar Retail products

The main objective of the project is to establish a retail product produced from Molinia biochar. One method already used by businesses in several countries is using biochar mixed with compost. It is recommended to mix biochar with compost (International Biochar Initiative, 2018) before use. The first part of this project will be to try and develop a compost to mix with the biochar which could be sold as a retail product. The second part of the project will be to research and establish an innovative retail product from the pure biochar.

2. Sheep manure Compost

2.1 Preliminary research

Upland farms remove the sheep from habitat rich land during the winter months to ensure to reduce environmental damage by overgrazing and to comply with Agri-environment schemes. Often these sheep are housed in sheds, when the sheds are cleaned out the problem of surplus manure arises. Often the manure cannot be spread on land near as this is often habitat land. Spreading the manure on habitat land could potentially have undesirable effects on the herbage rich meadows.

Sheep in wintered in sheds at Henfron farm use Molinia as a bedding. Preliminary research has already revealed that sheep manure is an excellent garden fertiliser with a high Phosphorus and Potassium content essential for plant growth (DEFRA, 2002). Previously composted sheep manure has already been analysed with promising results (Appendix 1.). To compost adequately temperatures should reach at least 50° to kill pathogens (Rodale Institute, 2017) but not exceed 65°C as beneficial microorganisms can be killed (Permaculture, 2017).

2.2 Experiment

Four bays of partly composted sheep manure and bedding were created by shredding the manure through a small manure spreader. Pile No.1 was shredded weekly, pile No. 2 every two weeks, pile No. 3 every four weeks and pile No.4 after six weeks. This process was continued for a total of 12 weeks. The PAS 100 is the minimum requirement for composted materials (Eurofins, 2018). Samples are tested for human pathogen indicator organisms, potentially toxic elements, physical contaminants and weed propagules. In addition the samples are also tested for primary and secondary nutrients and minimum performance in plant germination and growth tests.

Sheep manure and bedding in sheep shed

Loading manure into shredder

Four piles of composting manure

Re-shredding process

After eight and twelve weeks a sample from each pile was sent off for analysis, PAS100 results will be available from the first analysis at 8 weeks, This project will also carry on for 12 weeks to ensure that the accreditation is achieved.

Temperatures were recorded daily from four points in each pile and the moisture content measured weekly with water added as necessary.

2.2 Results

2.2.1 PAS100 Analysis

The following table summarises the results from the PAS 100 analysis. The first four samples of compost (1, 2, 3 and 4) were taken after eight weeks with the following four samples of compost (5, 6, 7 and 8) taken at the end of the experiment (12 weeks).

Summary of the PAS 100 results

			Compost results					
	Dry Matter	pH	N (%/dm)	P (%/dm)	K (%dm)	plants germinated (%)	Plant growth mass (%)	Results
Sample 1	40.1	7.7	3.42	0.89	2.1	96.67	94.67	Pass
Sample 2	38.5	7.8	1.34	0.36	0.89	86.67	68.63	Fail
Sample 3	45.9	7.9	3.34	0.87	2.1	100	119.98	Pass
Sample 4	30.1	7.9	6.08	0.89	2.5	96.67	112.02	Pass
Sample 5	41	7.8	3.59	0.67	2.1	96.43	28.59	Fail
Sample 6	38.6	7.9	3.68	0.71	2.3	107.4	75.06	Fail
Sample 7	49	8	3.52	0.69	2.2	107.14	75.63	Fail
Sample 8	30.5	8.1	3.56	0.7	2.3	107.14	101.14	Pass

Four samples failed the ‘plant growth mass %’ experiment, these four are highlighted in red. To gain PAS100 accreditation, the plants had to weigh at least an average of 80 grams after 28days.

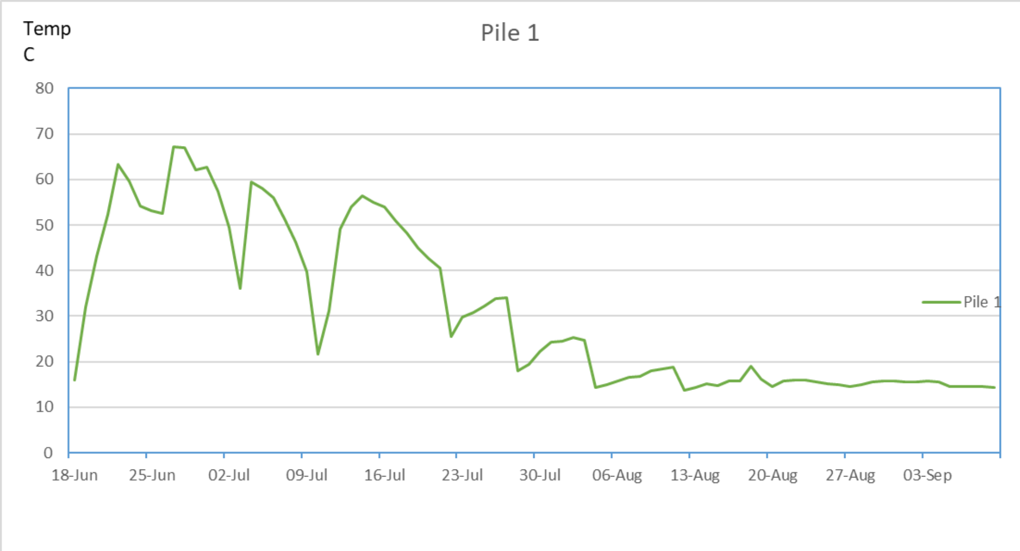
A summary of results from samples 1 and 2 are in appendix 2. The full results of all samples are available upon request.

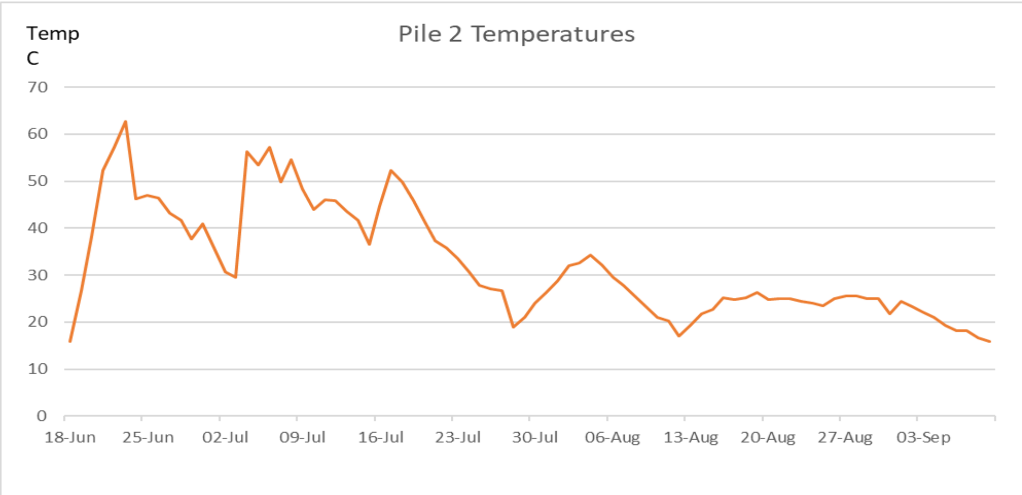
Tony Davies, Welsh Biochar Project

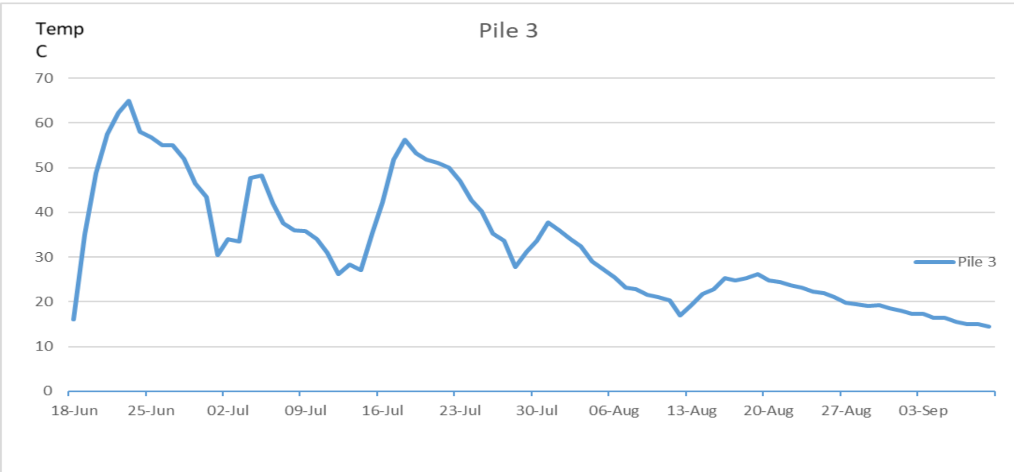
2.2.2 Composting process

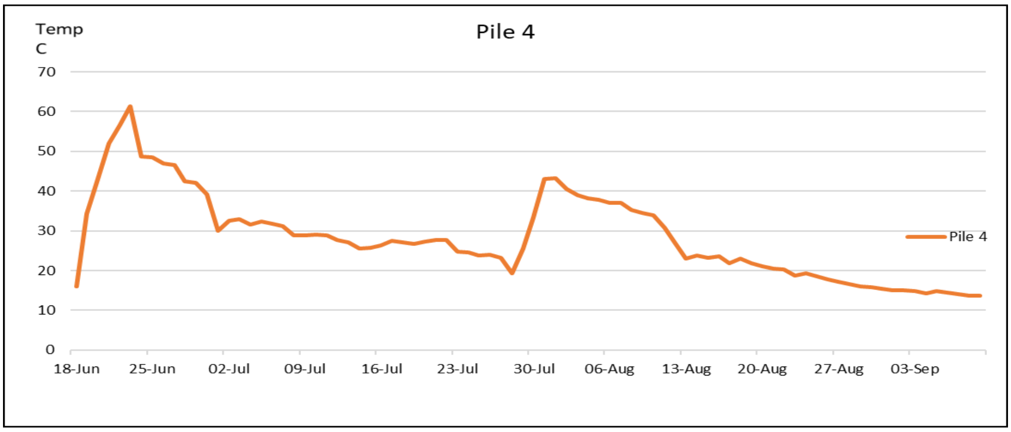
The following graphs highlight the temperature of the compost piles for the twelve weeks. Appendix 3 contains the temperature spreadsheets.

The peaks in the graphs (higher temperatures) correspond with the re-shredding of the compost.









Compost particle size

		Particle size Passed through					
		12.5mm Sieve (%)	Average %	8mm Sieve (%)	Average %	4mm Sieve (%)	Average %
8 weeks	Sample 1	94.82		87.6		69	
	Sample 2	94		85		62	
	Sample 3	85		72		52	
	Sample 4	90	90.955	67	77.9	42	56.25
12 weeks	Sample 5	99		97		83	
	Sample 6	99		90		70	
	Sample 7	99		87		65	
	Sample 8	94	97.75	78	88	47	66.25

The above table shows the percentage of the compost that passed through various sizes of sieve.

2.3 Conclusion

The actual composting process was successful with adequate temperatures reached quickly. This experiment was very useful in proving that used animal bedding does compost extremely well with high temperatures reached killing all the pathogens etc. A lot of useful data on moisture content and time needed to compost has been collected.

Unfortunately, as four of the eight samples failed the minimum performance in plant germination and growth tests the product produced cannot be described as compost. Whilst analysing the results it became clear that the low nutrient quality of Molinia used as bedding was the probable cause.

The experiment could have various results if different machinery was used to shred the manure. If the composting was completed outdoors the moisture content and temperature could have varied, this could also have also resulted in a different outcome.

The original plan was to distribute biochar mixed with this compost to gardeners and garden centres in the Powys with information sheets and feedback forms. This part of the project was discontinued due to the failure of the PAS100 accreditation, however a few gardeners who had visited the project did request some compost, so a few bags were distributed locally.

The experiment could be continued by adding other waste products to the composting process. Research has highlighted lower quality sheep's wool and bracken as possible additions.

3. Biochar Retail product

3.1 Introduction

This section of the project was to research and establish a high value retail Biochar project for the retail market.

3.2 Primary Research

Initial research has highlighted many opportunities to process biochar into retail products. The following products are a sample of biochar usage: a soil conditioner, a livestock feed additive, water and waste filtration, a colouring agent, in cosmetics, in medicines, in energy production, animal feed additive, water/sewage treatment, dehumidifier, soil additive, colouring agent, Insulation, air/water filtration, treating pond water, decontamination, cosmetics, fuel, clothing/food die, pet litter trays and for detoxification by the NHS (Ithaka, 2017).

Researched discovered a product which appeared worth pursuing. Biochar is marketed in several countries as a natural dehumidifier and for use in air fresheners. There are already businesses in the USA using bamboo biochar imported from China for use in air fresheners and dehumidifiers.

Air purifying bags

"The Moso Natural Air Purifying Bag is the easiest way to maintain a fresh, dry and odor free environment. Without using batteries or wires, the Moso Bag will work continuously to remove odors, allergens and harmful pollutants from the air. In damp, musty environments the Moso Bag will absorb excess moisture to prevent mold, mildew and bacteria from forming. (Mosa, 2017)

3.3 Experiment

It was decided to experiment with a small pilot project using Molinia biochar. A problem was encountered during packaging due to the small particle size of Purple Moor Grass biochar. Even when the biochar was double bagged some biochar dust was still leaking. A pilot project was completed collating data on the quantity of moisture the bags absorbed in locations with different levels of humidity.

A small number of cotton pouches have been purchased for the initial experiments. Six bags have been filled with biochar, weighed and strategically placed in different locations.

Molinia biochar in pouches

The pouches will be weighed periodically to assess how much moisture has been absorbed.

3.4 Results

The following tables explains the weight gain by the pouches.

Sample	location	07-Feb	22-Feb	12-Apr	09-May	15-Jul	Weight gain	Moisture gain
		g	g	g	g	g	g	(%)
A	Wardrobe	121	116	115	122	125	4	3.31
B	Car	108	111	110	110	112	4	3.70
C	Utilty room	116	121	119	119	122	6	5.17
D	Outbuilding	118	123	122	122	125	7	5.93
E	Damp corner of a room	127	131	132	131	133	6	4.72
F	Working boots	125	128	129	130	130	5	4.00

3.5 Conclusion

A maximum of 5.9% moisture weight gain was recorded. Due to the small amounts of moisture absorbed it was decided to discontinue with this section of the project. It could be assumed Molinia biochar is not as porous as bamboo biochar.

Tony Davies, Welsh Biochar Project

4. Biochar Soil Conditioner

4.1 Primary Research

It was decided to gain feedback from potential users of Biochar on their knowledge and interpretation of biochar. According to (UK Biochar Research centre, 2017) *“The results of field trials can be difficult to interpret due to the fact that it is very hard, often impossible, to control all the independent variables.”*
It was decided not to pursue the compost section of the experiment by distributing bags of compost for feedback as the product could not legally be described as compost without the PAS100 Accreditation. However due to interest by a small number of local gardeners who had visited the project it was decided to distribute bags of biochar with feedback forms (appendix 4). Although time was not available for actual growing trials it was hoped to gain local perception of biochar.

4.2 Experiment

Information sheets, feedback forms and 50 17litre bags of Molinia biochar were distributed to visitors of the project and any other interested persons.

4.3 Results

A total of 12 feedback forms were returned with the addition of some verbal comments from other users.

Of the 12 returned forms six had heard of biochar previously. Most were unsure of how they were going to use the biochar.

4.4 Conclusions

The number of feedback forms returned was too low to justify any real conclusions. While this feedback part of the project was not successful it could be deemed successful that 50 members of the interested public received bags of biochar which will hopefully all be used in soil or compost.

5. Overall Conclusions

Although this project has had little success in achieving its initial objectives section of the project should still be considered successful. The actual composting of the sheep bedding was successful with correct temperatures and adequate particle size achieved. Fifty bags of pure biochar have been distributed raising awareness of biochar. The innovate nature of this project combined with biochar increasingly being mentioned in the agricultural and environmental press during the project ensured that there has been plenty of interest in this project.

Tony Davies, Welsh Biochar Project

Whilst the above experiments were being completed several academic papers were published with evidence proving biochar to be have excellent carbon sequestration qualities.

The funded removed the financial risk given the incentive to proceed with the biochar-based experiments. Biochar is not a new concept but globally it is rapidly gaining momentum as a credible form of carbon sequestration. According to a press article (Inside, 2017) the global biochar market is forecast to increase by 14% annually. Biochar is a potential solution to help Wales meet the emissions targets in the Environment Bill (Welsh Government, 2016). The results from this project are being used as a starting point in Molinia experiments to assist in the 'Heritage Lottery Funded' project 'Elan Links' (Elan Valley Trust, 2017).

6. Appendices

Appendix 1 Sheep manure analysis

eurofins

Tony Davies
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Henfron, Elan Valley
Rhayader
GB
ld65he

PO Number 34721

AR-16-UD-054042-01

Reported on 25/02/2016
Reported by Sarah Smith, Analytical Services Manager

Page 1 of 1

Certificate Of Analysis

Sample number	**400-2016-45000005**	Received on	**05/01/2016**
Your sample reference	**Sheep manure compost**	Your sample code	**Henfron 1**

	Test Code	Analyte	Result		Result for interpretation
	Elements				
	† UD496	Total Calcium	14000	mg/kg dm	11.31 kg/t as CaO ¦ 22.62 units/ton as CaO fresh b
	† UD495	Total Magnesium	7040	mg/kg dm	6.73 kg/t ¦ 13.47 units/ton (as MgO fresh basis)
	† UD498	Total Phosphorus	4880	mg/kg dm	6.45 kg/t ¦ 12.90 units/ton (as P2O5 fresh basis)
	† UD497	Total Potassium	4090	mg/kg dm	2.84 kg/t ¦ 5.69 units/ton (as K20 fresh basis)
	† UD494	Total Sulphur	2110	mg/kg dm	3.04 kg/t ¦ 6.09 units/ton (as SO3 fresh basis)
*	† UD609	Ammonium-N	173	mg/kg dm	0.10 kg/t ¦ 0.20 units/ton (as NH4-N fresh basis)
*	† UD492	Dry Matter in organic solid wastes	577	g/kg	
*	† UD493	pH	6.90		
*	† UD610	Total Nitrogen (Kjeldahl)	2.44	g/100 g DM	14.08 kg/t ¦ 28.16 units/ton (as N fresh basis)

Unless stated, all results are expressed on a sample as received basis.
† Indicates that this test was subcontracted

* Indicates that this parameter is not included in the UKAS accreditation schedule for the laboratory.
Opinions and/or interpretations within this report are outside our accreditation scope.

Key: cfu colony forming units
< denotes less than
> denotes greater than
~ estimated value

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Appendix 2 Sample1

eurofins

A B Davies
A B Davies
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Elan Valley
Rhyadar
LD6 5HE

Analytical Report Code AR-16-UD-286523-01
Report validated on 30/09/2016

Certificate of Analysis

Laboratory sample number	**400-2016-40005066**	Received on	**18/08/2016**
Client sample description	**Sheep manure compost**	Client sample code	**Henfron Sample 1**

SUMMARY SECTION

Parameter	Result	PAS 100 Upper Limit	Units	Pass / Fail	Method Reference
E. coli	<10	1000	CFU/g	Pass	EUMM3.02
Salmonella spp	Not Detected	0	/25g	Pass	Micro/190
Cadmium as Cd	0.5	1.5	mg/kg DM	Pass	ICP/003
Chromium as Cr	2.50	100	mg/kg DM	Pass	ICP/003
Copper as Cu	22.0	200	mg/kg DM	Pass	ICP/003
Lead as Pb	13.0	200	mg/kg DM	Pass	ICP/003
Mercury as Hg	<0.1	1	mg/kg DM	Pass	I/052
Nickel as Ni	5.5	50	mg/kg DM	Pass	ICP/003
Zinc as Zn	170	400	mg/kg DM	Pass	ICP/003
CO_2 (stability)	4	16	mg CO_2/g organic matter/day	Pass	
Weed plants	0.00	0	number growing	Pass	BIO/001
Glass / metal / plastic / other [1]	0.000	0.25	% of 'air-dry' sample > 2mm	Pass	CALC/001
Plastic	0.000	0.12	% of 'air-dry' sample > 2mm	Pass	CALC/001
Stones in 'mulch'	6	10	% of 'air-dry' sample > 4mm	Pass	CALC/001
Stones in other than 'mulch'	6	8	% of 'air-dry' sample > 4mm	Pass	CALC/001
		PAS 100 Lower Limit			
Plants germinated	96.67	80	number of plants, tests as % of controls	Pass	CALC/001
Plant top growth	94.67	80	average g/plants, tests as % of controls	Pass	CALC/001

1 Excluding stones.

*Please note that all testing is subcontracted within the Eurofins group of laboratories

Overall Assessment Pass if all the above are 'Pass'. Fail if any of the above results are 'Fail'. - **Pass**

A B Davies
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Henfron
Elan Valley
Rhyadar
LD6 5HE

Analytical Report Code AR-16-UD-286521-01
Report validated on 30/09/2016

Certificate of Analysis

Laboratory sample number	**400-2016-40005064**	Received on	**18/08/2016**
Client sample description	**Sheep manure compost**	Client sample code	**Henfron Sample 2**

SUMMARY SECTION

Parameter	Result	PAS 100 Upper Limit	Units	Pass / Fail	Method Reference
E. coli	<10	1000	CFU/g	Pass	EUMM3.02
Salmonella spp	Not Detected	0	/25g	Pass	Micro/190
Cadmium as Cd	0.5	1.5	mg/kg DM	Pass	ICP/003
Chromium as Cr	12.0	100	mg/kg DM	Pass	ICP/003
Copper as Cu	23.0	200	mg/kg DM	Pass	ICP/003
Lead as Pb	10.0	200	mg/kg DM	Pass	ICP/003
Mercury as Hg	<0.1	1	mg/kg DM	Pass	I/052
Nickel as Ni	13.0	50	mg/kg DM	Pass	ICP/003
Zinc as Zn	180	400	mg/kg DM	Pass	ICP/003
CO_2 (stability)	12	16	mg CO_2/g organic matter/day	Pass	
Weed plants	0.00	0	number growing	Pass	BIO/001
Glass / metal / plastic / other [1]	0.000	0.25	% of 'air-dry' sample > 2mm	Pass	CALC/001
Plastic	0.000	0.12	% of 'air-dry' sample > 2mm	Pass	CALC/001
Stones in 'mulch'	0	10	% of 'air-dry' sample > 4mm	Pass	CALC/001
Stones in other than 'mulch'	0	8	% of 'air-dry' sample > 4mm	Pass	CALC/001
		PAS 100 Lower Limit			
Plants germinated	86.67	80	number of plants, tests as % of controls	Pass	CALC/001
Plant top growth	68.63	80	average g/plants, tests as % of controls	Fail	CALC/001

[1] Excluding stones.

*Please note that all testing is subcontracted within the Eurofins group of laboratories

Overall Assessment Pass if all the above are 'Pass'. Fail if any of the above results are 'Fail'. - **Fail**

This sample has exceeded the limit stated in the PAS100 standard for one or more parameters, please refer to your Quality Protocol or contact your certification body or REAL for guidance on corrective actions.

Appendix 3 Temperature and moisture content spreadsheets

Pile No.	1		Temperature C					Moisture content (%)		
Day	Date	Water (Litres)	Right	Middle	Left	back	Average	Left	Right	Comments
Sat	18-Jun	60	16	16	16	16	16	51	44	Shredded 1
Sun	19-Jun	20	26	34	39	29	32	58	62	
Mon	20-Jun		35	46	48	44	43	56	58	
Tue	21-Jun		52	54	51	52	52	56	58	
Wed	22-Jun		60	66	64	63	63	54	56	
Thu	23-Jun		56	61	58	64	60	53	55	
Fri	24-Jun		47	52	53	65	54	51	53	
Sat	25-Jun	20	43	54	52	64	53	49	51	Shredded 2
Sun	26-Jun		52	67	35	56	53	63	65	
Mon	27-Jun		64	73	61	71	67.25	64	66	
Tue	28-Jun		66	70	62	70	67	63	65	
Wed	29-Jun		59	64	55	70	62	62	64	
Thu	30-Jun		59	68	54	70	62.75	54	56	
Fri	01-Jul		54	61	47	68	57.5	51	53	
Sat	02-Jul	60	50	52	34	62	49.5	47	49	Shredded 3
Sun	03-Jul		39	37	31	37	36	61	63	
Mon	04-Jul		58	66	54	60	59.5	60	62	
Tue	05-Jul		55	55	57	65	58	60	62	
Wed	06-Jul		51	57	50	66	56	58	60	
Thu	07-Jul		45	51	42	67	51.25	57	59	
Fri	08-Jul		37	41	42	65	46.25	54	56	
Sat	09-Jul		30	36	35	58	39.75	53	55	
Sun	10-Jul	20	20	25	22	20	22	50	52	Shredded 4
Mon	11-Jul		30	34	28	33	31	64	66	
Tue	12-Jul		46	48	47	55	49	65	67	
Wed	13-Jul		52	55	44	65	54	64	66	
Thu	14-Jul		55	56	50	65	56.5	64	66	
Fri	15-Jul		54	53	48	65	55	63	65	
Sat	16-Jul		53	51	47	65	54	60	62	
Sun	17-Jul		48	47	46	63	51	59	61	
Mon	18-Jul		45	44	46	58	48.3	58	60	
Tue	19-Jul		40	42	43	55	45	56	58	
Wed	20-Jul		38	41	41	50	42.5	54	56	
Thu	21-Jul	20	36	40	40	46	40.5	52	54	Shredded 5
Fri	22-Jul		25	26	24	27	25.5	67	69	
Sat	23-Jul		30	32	25	32	29.75	67	69	
Sun	24-Jul		31	31	21	40	30.75	66	68	
Mon	25-Jul		32	31	22	44	32.25	65	67	
Tue	26-Jul		34	32	22	47	33.75	65	67	
Wed	27-Jul		34	37	22	43	34	60	62	
Thu	28-Jul		19	19	16	18	18	60	62	Shredded 6
Fri	29-Jul		17	20	20	21	19.5	59	61	
Sat	30-Jul		21	21	20	27	22.25	58	60	
Sun	31-Jul		25	25	20	27	24.25	57	59	
Mon	01-Aug		23	25	20	30	24.5	57	59	
Tue	02-Aug		25	25	21	30	25.25	54	56	
Wed	03-Aug	20	24	24	21	30	24.75	50	52	Shredded 7
Thu	04-Aug		14	15	12	16	14.25	59	61	
Fri	05-Aug		15	15	12	18	15	59	61	
Sat	06-Aug		16	16	12	19	15.75	58	60	
Sun	07-Aug		17	16	13	20	16.5	58	60	
Mon	08-Aug		17	16	13	21	16.75	59	61	
Tue	09-Aug		18	17	14	23	18	57	59	
Wed	10-Aug		19	17	14	24	18.5	57	59	
Thu	11-Aug		19	18	14	24	18.75	58	60	Shredded 8
Fri	12-Aug		14	13	13	15	13.75	58	60	
Sat	13-Aug		15	14	12	16	14.25	57	59	
Sun	14-Aug		15	15	15	16	15.25	57	59	
Mon	15-Aug		14	15	12	18	14.75	56	58	
Tue	16-Aug		14	15	15	19	15.75	56	58	
Wed	17-Aug		14	15	15	19	15.75	54	56	
Thu	18-Aug		15	16	25	20	19	51	53	
Fri	19-Aug	40	16	15	14	20	16.25	50	52	Shredded 9
Sat	20-Aug		13	15	15	15	14.5	68	70	
Sun	21-Aug		15	16	16	16	15.75	67	69	
Mon	22-Aug		15	16	16	17	16	67	69	
Tue	23-Aug		16	15	16	17	16	65	67	
Wed	24-Aug		15	15	16	16	15.5	65	67	
Thu	25-Aug		15	15	16	15	15.25	65	67	
Fri	26-Aug		15	15	15	15	15	65	67	Shredded 10
Sat	27-Aug		14	15	14	15	14.5	64	66	
Sun	28-Aug		15	15	15	15	15	63	65	
Mon	29-Aug		15	15	16	16	15.5	62	64	
Tue	30-Aug		15	15	16	17	15.75	60	62	
Wed	31-Aug		15	15	16	17	15.75	60	62	Shredded 11
Thu	01-Sep		15	16	16	15	15.5	59	61	
Fri	02-Sep		15	16	15	16	15.5	58	60	
Sat	03-Sep		15	15	16	17	15.75	59	61	
Sun	04-Sep		15	14	16	17	15.5	58	60	
Mon	05-Sep		14	14	15	15	14.5	58	60	Shredded 12
Tue	06-Sep		14	14	15	15	14.5	58	60	
Wed	07-Sep		14	14	15	15	14.5	58	60	
Thu	08-Sep		14	15	15	14	14.5	58	60	
Fri	09-Sep		14	14	15	14	14.25	58	60	
Totals/Averages		260				36.5	32.8			

Pile No.	2		Temperature C					Moisture content		
Day	Date	Water (Litres)	Right	Middle	Left	back	Average			Comments
Sat	18-Jun	80	16	16	16	16	16	46	44	Shredded 1
Sun	19-Jun	20	26	25	26	30	26.75	65	63	
Mon	20-Jun		39	37	38	39	38.25	69	71	
Tue	21-Jun		51	49	51	58	52.25	68	70	
Wed	22-Jun		56	55	56	62	57.25	63	65	
Thu	23-Jun		62	62	61	66	62.75	60	62	
Fri	24-Jun		46	44	38	57	46.25	58	60	
Sat	25-Jun		48	43	43	54	47	56	58	
Sun	26-Jun		46	43	44	53	46.5	53	55	
Mon	27-Jun		42	41	37	53	43.25	53	55	
Tue	28-Jun		42	38	37	50	41.75	52	54	
Wed	29-Jun		31	35	37	48	37.75	49	51	
Thu	30-Jun		36	33	44	51	41	49	51	
Fri	01-Jul		30	30	35	48	35.75	50	52	
Sat	02-Jul	60	30	26	27	40	30.75	48	50	shredded 2
Sun	03-Jul		29	30	26	33	29.5	66	68	
Mon	04-Jul		55	66	48	56	56.25	65	67	
Tue	05-Jul		45	50	55	64	53.5	65	67	
Wed	06-Jul		53	61	52	63	57.25	63	65	
Thu	07-Jul		40	54	45	60	49.75	62	64	
Fri	08-Jul		47	56	53	62	54.5	62	64	
Sat	09-Jul		43	50	40	60	48.25	61	63	
Sun	10-Jul		39	45	32	60	44	58	60	
Mon	11-Jul		42	47	35	60	46	56	58	
Tue	12-Jul		34	44	45	60	45.75	56	58	
Wed	13-Jul		33	42	42	57	43.5	54	56	
Thu	14-Jul	20	32	40	40	55	41.75	50	52	Shredded 3
Fri	15-Jul		29	33	36	48	36.5	60	62	
Sat	16-Jul		34	43	47	55	44.75	60	62	
Sun	17-Jul		46	51	53	59	52.25	61	63	
Mon	18-Jul		44	47	50	58	49.75	62	64	
Tue	19-Jul		40	43	46	54	45.75	60	62	
Wed	20-Jul		36	39	40	50	41.25	59	61	
Thu	21-Jul		32	35	37	45	37.25	59	61	
Fri	22-Jul		37	33	28	45	35.75	58	60	
Sat	23-Jul		34	31	30	39	33.5	57	59	
Sun	24-Jul		30	30	28	35	30.75	58	60	
Mon	25-Jul		25	27	25	34	27.75	56	58	
Tue	26-Jul		25	24	25	34	27	53	55	
Wed	27-Jul		24	24	25	34	26.75	52	54	
Thu	28-Jul	40	18	19	19	20	19	40	42	Reshredded 4
Fri	29-Jul		20	21	20	23	21	68	70	
Sat	30-Jul		23	26	22	25	24	67	69	
Sun	31-Jul		23	24	24	34	26.25	65	67	
Mon	01-Aug		29	26	20	40	28.75	66	68	
Tue	02-Aug		30	30	26	42	32	64	66	
Wed	03-Aug		33	28	25	44	32.5	64	66	
Thu	04-Aug		32	30	29	46	34.25	59	61	
Fri	05-Aug		30	28	27	44	32.25	57	59	
Sat	06-Aug		28	24	26	40	29.5	56	58	
Sun	07-Aug		26	23	25	37	27.75	54	56	
Mon	08-Aug		24	23	23	32	25.5	54	56	
Tue	09-Aug		22	21	22	28	23.3	53	55	
Wed	10-Aug		21	20	20	23	21	50	52	
Thu	11-Aug	40	20	19	19	23	20.25	49	51	Reshredded 5
Fri	12-Aug		18	16	16	18	17	68	70	
Sat	13-Aug		20	18	18	21	19.25	67	69	
Sun	14-Aug		23	20	19	25	21.75	65	67	
Mon	15-Aug		22	21	18	30	22.75	64	66	
Tue	16-Aug		25	23	23	30	25.25	65	67	
Wed	17-Aug		25	23	21	30	24.75	63	65	
Thu	18-Aug		25	24	21	31	25.25	63	65	
Fri	19-Aug	40	27	24	20	34	26.25	63	65	
Sat	20-Aug		24	22	23	30	24.75	59	61	
Sun	21-Aug		24	24	24	28	25	59	61	
Mon	22-Aug		23	24	25	28	25	56	58	
Tue	23-Aug		23	24	25	26	24.5	52	54	
Wed	24-Aug		23	24	25	24	24	52	54	
Thu	25-Aug		23	24	25	22	23.5	50	52	Reshredded 6
Fri	26-Aug		24	25	26	25	25	66	68	
Sat	27-Aug		25	25	27	25	25.5	66	68	
Sun	28-Aug		25	25	27	25	25.5	65	67	
Mon	29-Aug		24	24	26	26	25	64	66	
Tue	30-Aug		24	24	26	26	25	64	66	
Wed	31-Aug		24	23	25	15	21.75	63	65	
Thu	01-Sep		23	24	25	26	24.5	62	64	
Fri	02-Sep		23	23	24	23	23.25	62	64	
Sat	03-Sep		22	23	22	22	22.25	61	63	
Sun	04-Sep		22	20	20	22	21	60	62	
Mon	05-Sep		20	18	18	21	19.25	60	62	
Tue	06-Sep		19	18	16	20	18.25	60	62	
Wed	07-Sep		19	17	16	21	18.25	58	60	
Thu	08-Sep		18	15	15	19	16.75	59	61	
Fri	09-Sep		17	15	15	17	16	58	60	
Totals/Averages		300				38.3	32.8			

Pile No.	3		Temperature C					Moisture content (%)		
Day	Date	Water (litres)	Right	Middle	Left	back	Average	left	Right	Comments
Sat	18-Jun	80	16	16	16	16	16	35	33	Shredded 1
Sun	19-Jun	20	35	38	34	33	35	48	51	
Mon	20-Jun		42	54	49	50	48.75	55	54	
Tue	21-Jun		47	61	61	61	57.5	54	53	
Wed	22-Jun		54	67	61	67	62.25	50	53	
Thu	23-Jun		60	69	61	70	65	53	54	
Fri	24-Jun		47	57	59	69	58	52	53	
Sat	25-Jun	30	43	56	58	70	56.75	48	48	
Sun	26-Jun		40	52	58	70	55	61	64	
Mon	27-Jun		43	51	58	68	55	59	58	
Tue	28-Jun		39	48	54	67	52	57	56	
Wed	29-Jun		30	41	50	65	46.5	57	54	
Thu	30-Jun		33	38	47	56	43.5	56	54	
Fri	01-Jul		25	24	33	40	30.5	51	50	
Sat	02-Jul	60	32	31	23	50	34	48	47	
Sun	03-Jul		25	30	28	51	33.5	71	66	
Mon	04-Jul		30	52	48	61	47.75	68	66	
Tue	05-Jul		30	49	53	61	48.25	67	64	
Wed	06-Jul		30	45	38	55	42	66	63	
Thu	07-Jul		28	37	35	50	37.5	66	62	
Fri	08-Jul		30	35	34	45	36	64	61	
Sat	09-Jul		30	32	35	46	35.75	62	57	
Sun	10-Jul		28	30	33	45	34	61	57	
Mon	11-Jul		25	25	28	46	31	57	54	
Tue	12-Jul		20	25	25	35	26.25	57	56	
Wed	13-Jul	20	24	24	25	40	28.25	53	56	Shredded 2
Thu	14-Jul		26	27	27	28	27	60	67	
Fri	15-Jul		39	32	34	36	35.25	59	67	
Sat	16-Jul		42	45	38	44	42.25	57	67	
Sun	17-Jul		50	51	48	58	51.75	57	65	
Mon	18-Jul		55	57	48	65	56.25	58	65	
Tue	19-Jul		50	54	46	63	53.25	56	65	
Wed	20-Jul		50	52	44	61	51.75	55	64	
Thu	21-Jul		50	50	43	61	51	56	67	
Fri	22-Jul		50	49	40	61	50	57	65	
Sat	23-Jul		47	44	36	61	47	54	67	
Sun	24-Jul		40	40	30	61	42.75	53	61	
Mon	25-Jul		38	37	30	56	40.25	55	58	
Tue	26-Jul		33	30	24	54	35.25	54	54	
Wed	27-Jul		30	30	24	51	33.75	52	54	
Thu	28-Jul	40	25	26	20	40	27.75	49	51	
Fri	29-Jul		29	29	22	45	31.25	61	61	
Sat	30-Jul		32	29	22	52	33.75	58	60	
Sun	31-Jul		40	34	22	55	37.75	58	60	
Mon	01-Aug		29	32	28	55	36	57	59	
Tue	02-Aug		32	30	23	51	34	65	67	
Wed	03-Aug		33	28	25	44	32.5	63	65	
Thu	04-Aug		30	24	24	38	29	62	64	
Fri	05-Aug		27	24	23	35	27.25	63	65	
Sat	06-Aug		25	22	23	32	25.5	62	64	
Sun	07-Aug		23	21	21	28	23.25	62	64	
Mon	08-Aug		23	21	21	26	22.75	63	65	
Tue	09-Aug		21	20	21	24	21.5	61	63	
Wed	10-Aug		21	20	20	23	21	55	57	
Thu	11-Aug		20	19	19	23	20.25	53	55	
Fri	12-Aug	40	18	16	16	18	17	49	51	Shredded 3
Sat	13-Aug		20	18	18	21	19.25	58	60	
Sun	14-Aug		23	20	19	25	21.75	57	59	
Mon	15-Aug		22	21	18	30	22.75	56	58	
Tue	16-Aug		25	23	23	30	25.25	54	56	
Wed	17-Aug		25	23	21	30	24.75	55	57	
Thu	18-Aug		25	24	21	31	25.25	55	57	
Fri	19-Aug	40	27	24	20	34	26.25	54	56	
Sat	20-Aug		24	22	23	30	24.75	54	56	
Sun	21-Aug		24	22	23	29	24.5	55	57	
Mon	22-Aug		23	22	22	28	23.75	54	56	
Tue	23-Aug		23	22	22	26	23.25	52	54	
Wed	24-Aug		22	21	22	24	22.25	53	55	
Thu	25-Aug		22	22	20	24	22	52	54	
Fri	26-Aug		21	21	20	22	21	52	54	
Sat	27-Aug		19	20	20	20	19.75	51	53	
Sun	28-Aug		19	19	20	20	19.5	50	52	
Mon	29-Aug	20	19	18	19	20	19	49	51	
Tue	30-Aug		18	18	20	21	19.25	64	61	
Wed	31-Aug		17	17	20	20	18.5	61	59	
Thu	01-Sep		17	17	19	19	18	60	58	
Fri	02-Sep		16	17	18	18	17.25	59	58	
Sat	03-Sep		16	17	18	18	17.25	58	57	
Sun	04-Sep		16	16	17	17	16.5	55	58	
Mon	05-Sep		16	16	17	17	16.5	56	58	
Tue	06-Sep		15	15	16	16	15.5	57	57	
Wed	07-Sep		15	15	15	15	15	58	57	
Thu	08-Sep		14	15	15	16	15	58	56	
Fri	09-Sep		14	14	14	16	14.5	58	57	
Totals/Averages		350					32.6			

Pile No.	4		Temperature C					Moisture content (%)		
Day	Date	Water (Litres)	Right	Middle	Left	back	Average	Left	Right	Comments
Sat	18-Jun	80	16	16	16	16	16	44	39	Shredded 1
Sun	19-Jun	20	36	33	36	32	34.25	58	56	
Mon	20-Jun		44	45	39	44	43	66	65	
Tue	21-Jun		50	58	44	56	52	66	64	
Wed	22-Jun		62	59	48	58	56.75	65	63	
Thu	23-Jun		73	60	52	60	61.25	65	63	
Fri	24-Jun		45	51	31	68	48.75	64	62	
Sat	25-Jun		41	49	40	64	48.5	64	62	
Sun	26-Jun		40	44	40	64	47	62	60	
Mon	27-Jun		41	43	38	64	46.5	62	60	
Tue	28-Jun		33	41	32	64	42.5	59	57	
Wed	29-Jun		33	35	37	63	42	57	55	
Thu	30-Jun		26	31	40	60	39.25	56	54	
Fri	01-Jul		25	25	23	47	30	52	50	
Sat	02-Jul	60	30	25	20	55	32.5	50	48	
Sun	03-Jul		33	25	20	54	33	65	63	
Mon	04-Jul		26	26	24	50	31.5	65	63	
Tue	05-Jul		25	27	25	52	32.25	676	674	
Wed	06-Jul		26	27	23	51	31.75	59	57	
Thu	07-Jul		30	25	22	48	31.25	61	59	
Fri	08-Jul		20	25	22	48	28.75	60	58	
Sat	09-Jul		26	22	20	47	28.75	60	58	
Sun	10-Jul		25	24	20	47	29	59	57	
Mon	11-Jul		25	25	22	43	28.75	58	56	
Tue	12-Jul		25	24	20	42	27.75	58	56	
Wed	13-Jul		22	23	20	43	27	57	55	
Thu	14-Jul		23	20	20	39	25.5	57	55	
Fri	15-Jul		23	22	20	38	25.75	56	54	
Sat	16-Jul		23	22	22	38	26.25	57	55	
Sun	17-Jul		24	23	24	39	27.5	56	54	
Mon	18-Jul		24	23	23	38	27	56	54	
Tue	19-Jul		24	24	23	36	26.75	55	53	
Wed	20-Jul		23	24	26	36	27.25	56	54	
Thu	21-Jul		24	25	28	34	27.75	54	52	
Fri	22-Jul		24	23	25	39	27.75	53	51	
Sat	23-Jul		23	22	22	32	24.75	3	1	
Sun	24-Jul		22	21	20	35	24.5	53	51	
Mon	25-Jul		21	20	22	32	23.75	52	50	
Tue	26-Jul		24	20	20	32	24	51	49	
Wed	27-Jul		22	21	20	30	23.25	50	48	
Thu	28-Jul	40	19	18	20	20	19.25	49	47	Shredded 2
Fri	29-Jul		24	25	25	28	25.5	68	66	
Sat	30-Jul		33	33	32	35	33.25	67	65	
Sun	31-Jul		40	40	44	48	43	67	65	
Mon	01-Aug		44	44	40	45	43.25	67	65	
Tue	02-Aug		40	42	35	45	40.5	65	63	
Wed	03-Aug		36	40	37	43	39	66	64	
Thu	04-Aug		36	39	35	43	38.25	64	62	
Fri	05-Aug		35	39	34	43	37.75	63	61	
Sat	06-Aug		33	38	34	43	37	60	58	
Sun	07-Aug		33	38	35	42	37	8	6	
Mon	08-Aug		30	37	33	41	35.25	56	54	
Tue	09-Aug		28	36	33	41	34.5	53	51	
Wed	10-Aug		27	35	33	41	34	52	50	
Thu	11-Aug	40	25	30	30	38	30.75	52	50	
Fri	12-Aug		22	25	25	35	26.75	67	65	
Sat	13-Aug		20	22	20	30	23	65	63	
Sun	14-Aug		23	21	21	30	23.75	64	62	
Mon	15-Aug		22	20	21	30	23.25	62	60	
Tue	16-Aug		23	20	23	28	23.5	61	59	
Wed	17-Aug		20	20	21	26	21.75	58	56	
Thu	18-Aug		20	22	23	27	23	57	55	
Fri	19-Aug	40	21	21	20	25	21.75	53	51	
Sat	20-Aug		19	20	21	24	21	65	63	
Sun	21-Aug		18	19	21	24	20.5	65	63	
Mon	22-Aug		18	19	20	24	20.25	65	63	
Tue	23-Aug		17	18	20	20	18.75	656	654	
Wed	24-Aug		17	19	19	22	19.25	65	63	
Thu	25-Aug		16	18	19	21	18.5	65	63	
Fri	26-Aug		16	17	18	20	17.75	64	62	
Sat	27-Aug		16	16	18	19	17.25	65	63	
Sun	28-Aug		15	16	17	18	16.5	65	63	
Mon	29-Aug		15	16	15	18	16	64	62	
Tue	30-Aug		15	15	16	17	15.75	65	63	
Wed	31-Aug		15	15	15	17	15.5	65	63	
Thu	01-Sep		14	15	15	16	15	64	62	
Fri	02-Sep		14	16	14	16	15	65	63	
Sat	03-Sep		14	15	15	15	14.75	64	62	
Sun	04-Sep		14	14	14	15	14.25	63	61	
Mon	05-Sep		14	14	15	16	14.75	63	61	
Tue	06-Sep		14	14	14	16	14.5	64	62	
Wed	07-Sep		13	14	14	15	14	62	60	
Thu	08-Sep		13	13	14	15	13.75	61	59	
Fri	09-Sep		13	13	14	15	13.75	58	56	
Totals/Averages		280				36.3	28.5			

Appendix 4

Innovate Solutions to Rural Issues

Arwain— The Leader Programme in Powys is funding a
Welsh Biochar project.

Please circle answer.

1, Have you heard of Biochar? Yes no If no go to question 4

2, Were you aware of its carbon storage properties? Yes no

3, Were you aware of its soil conditioner properties? Yes no

4, Do intend using your biochar as a compost additive? yes no

5, Do you intend using your biochar as a soil conditioner? Yes no

6, Do you intend using your biochar for both? Yes no

7, Any comments

Please return (using SAE supplied) to Welsh Biochar Project, Henfron Farm, Elan Valley, Rhayader, Powys, LD6 5HE or email answers to tony@henfron.co.uk or phone 01597 811240

Thank you for your help

Cronfa Amaethyddol Ewrop ar gyfer Datblygu Gwledig; Ewrop yn Buddsoddi mewn Ardaloedd Gwledig.
The European Agricultural Fund for Rural Development: Europe investing in Rural areas.

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