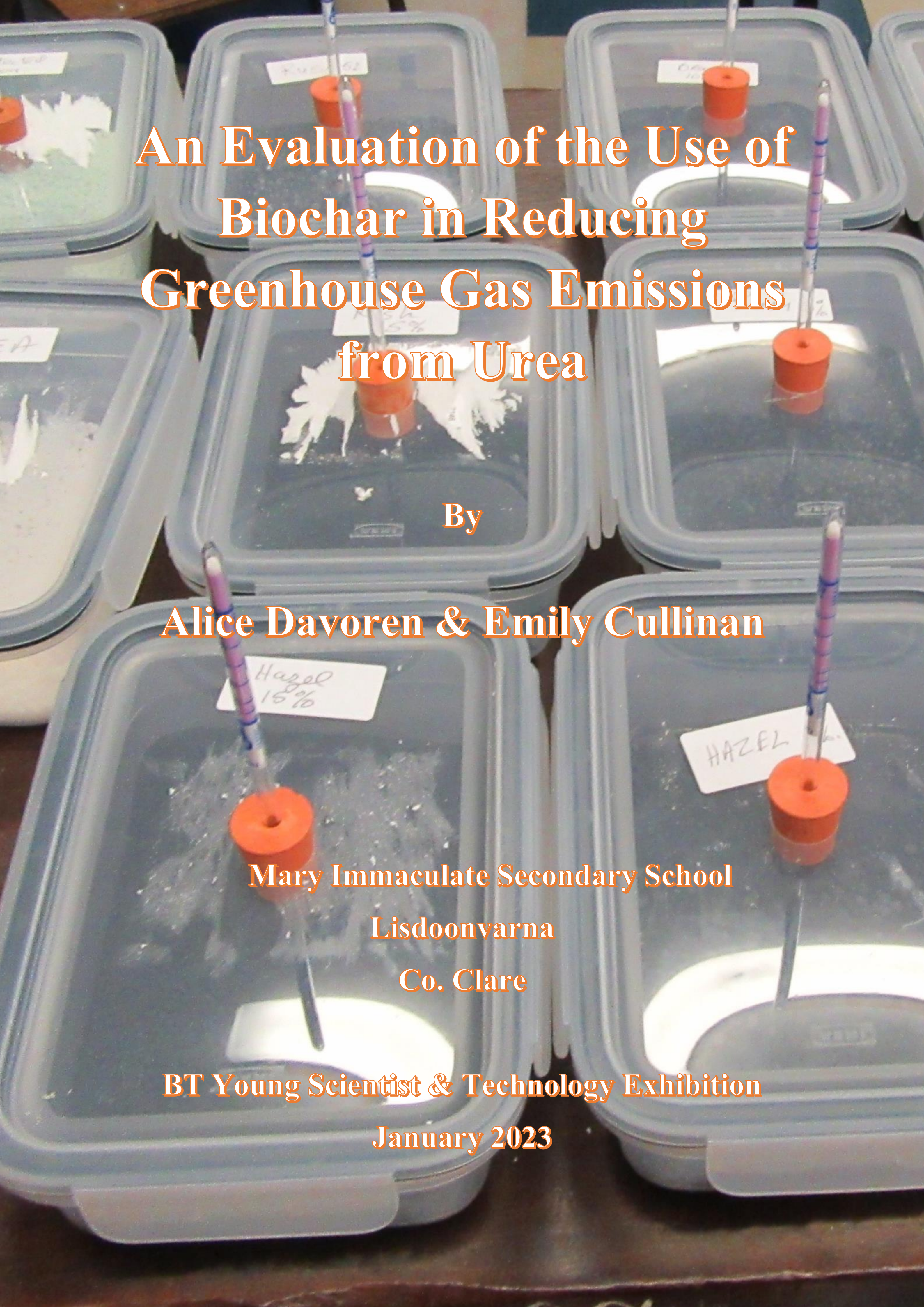

An Evaluation of the Use of Biochar in Reducing Greenhouse Gas Emissions from Urea

By

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BT Young Scientist & Technology Exhibition
January 2023

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Summary

We wanted to do this project to see if there is a better and more cost-effective way to reduce greenhouse gas emissions when using nitrogen fertilisers on a farm. We both come from farming backgrounds and we are both particularly interested on finding sustainable ways to reduce greenhouse gas emissions and make farming more environmentally friendly. We both care deeply about preserving Ireland's farming heritage yet understand that it is essential that the modernization is completed in an environmentally friendly way. This is what inspired us to create our project.

Studies on biochar have shown that it improves soil health and can also reduce damage to the environment. Biochar is a charcoal like substance, formed by burning rushes, scrub and other natural materials, in a process called pyrolysis. When biochar is in soil, it creates a secure place for carbon to be stored for a long time. It reduces the need for fertilisers in soil due it's enriching benefits.

Urea is used as a nitrogen fertiliser but isn't environmentally friendly, as urea releases ammonia gasses through nitrogen loss, which harms the atmosphere. Protected urea has been treated with a urease inhibitor. With an N, P, K ratio of 49-0-0, urea's nitrogen levels are greatly beneficial for soil and are therefore very popular within the agricultural sector. Farmers need to start adapting their farming methods to cope with climate change. The agriculture sector was responsible for 37.5% of greenhouse gas emissions in Ireland in 2021.

Our project hopes to combat the rapid rise of greenhouse gas emissions by promoting a greener and safer way to fertilise one's soil. We hope that our experiments will support our hypothesis that the inclusion of a biochar coating will create a carbon sink, therefore reducing our CO^2 emissions and reduce ammonia emissions.

The aims of our project are:

- To see if coating urea with different amounts of biochar would reduce the release of ammonia by the urea.
- To see if different types of biochar would give different results.
- To compare our emissions with those of the urea and protected urea.

To carry out our research we used IKEA food containers with a sealable lid. The container is 1L in size (192.690.79). These have a good seal and trap the ammonia released due to their airtight nature. We then made a hole in the lid of these containers before placing the ammonia gas detector in a rubber bung which was then securely placed in the hole. We began to observe the amount of ammonia released daily which was visible within two to four days. We recorded our results daily. The same amount of urea was used in each experiment in any particular trial. Each experiment was carried out 6 times for maximum accuracy.

Our initial two treatments ran as follows: Urea, protected urea and urea with three different types of biochar (rush, hazel, and bracken) each at three different concentrations of biochar (5%, 10%, 15%). We ran this experiment for four days, monitoring progress daily. However, by day four, we noticed that the results were incredibly slow to appear and, upon reflection, we found that this was due to the original experiment's lack of moisture. Therefore, this trial left us with inaccurate and unreliable results.

Before conducting our second trial, we contacted Mr Patrick Forrestal, a soil health specialist working with Teagasc, who advised us to introduce moisture into our experiment, a suggestion backed by our previous trials. We calculated the area of the containers in order to find the correct measurements for both our urea and our biochar. The average application is 250kg of urea-based fertilizer per hectare, meaning that 0.5g of urea per container would suffice for our experiment.

In this trial, we did not weigh out our biochar. Instead, we ground each type of biochar down, then sieved it before combining it with urea, ensuring that each granule of fertilizer was completely coated. We hand-picked each newly coated granule and placed it into our containers, then containing 1cm of soil, which we dampened with 30ml of water, before sealing them and beginning the waiting process. This trial, while it did deliver results, was still too slow and so we conducted more tests.

The next round of experiments we held were using 20g of urea and 15% biochar. We also experimented with 5% and 10% of biochar. We did this to see if we would get a faster result. We did seven experiments in this round, for each type of biochar. One out of each of the seven experiments was done using one of the faster ammonia gas detectors. Once more, we weighed out our urea (20g in this trial) and thoroughly coated them in a beaker using each of the finely ground biochar powders. We used 1cm of soil in a container and, to speed up our results, added 30ml of water to each container to ensure that there was enough moisture present. We watched these closely every day for 5 days and found that there was a much higher and quicker result than using the smaller measurements of urea.

Our final round of trials we did was using 5g of urea fertiliser and 15%, 10% and 5% of biochar, which is 0.75g, 0.5g and 0.25g respectively. For each type of biochar, we did 6 experiments using 15% biochar, and two of each using 5% and 10%. We conducted this trial in the same way we did for the others. We weighed out the urea and biochar, coated the urea in the biochar and evenly spread it over the soil that we dampened with 30ml of water. We sealed the containers and observed the results over four days. New ammonia detectors were used for each experiment. The controls we used was that we ran the experiment with soil only. We also ran all experiments with urea only and protected urea.

Date	1 Day	2 Days	3 days	4 days	5 days
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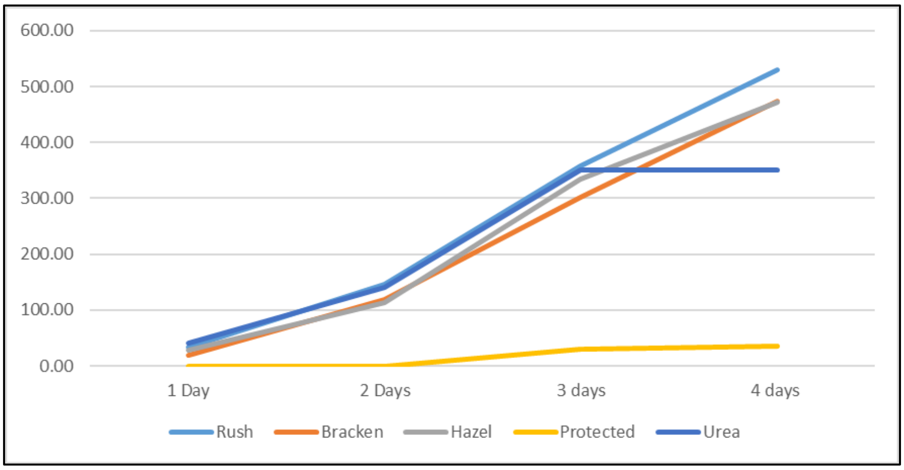
Rush F	40	120	390	550	Full
Rush G	50	210	430	600	Full

20g of Urea Coated with Rush Results (ppm).



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Our second aim was to see if different types of biochar would give different results. After running many different trials with different ratios of biochar, we can conclude that the type of biochar had very little effect on our outcome overall. Initially, we theorized that the biochar containing the least moisture (hazel) would absorb ammonia better, as moisture works as a catalyst to speed up the urease reaction. However, our trials proved that, after four days, the level of absorption was the same in every experiment.

Our final aim was to compare the emissions from urea to those of protected urea. Here we saw our most notable results. Our trials found that, the protected urea had released little to no gas by day four, and when coated with biochar, this release was slowed even further. Our ammonia gas detectors ranged from around 400 to 500ppm when used to measure the untreated urea. These results were in stark contrast to the protected urea, which never reached above 10ppm. Our results support the use of protected urea, which is already widely recommended for use within the Irish agricultural sector.

We take great pride in the accuracy of our chosen method. Each experiment took place in a controlled environment ensuring the reliability of our results. Our chosen containers worked perfectly to inhabit the experiment and, mainly, to ensure that no gas whatsoever escaped; it was all directed into the detector. Like many investigations, it was a process of trial and error in order to find the most conclusive method and fortunately, we discovered this method (the incorporation of individually coated urea granules into the damp soil) rather early on.

If we were to expand further on our project, we would be interested in conducting outdoor trials. We would also pay closer attention to our soil health before and after the inclusion of the biochar coated urea. Monitoring the soils pH levels would be particularly beneficial as we now know that the ammonium carbonate breakdown reaction is basic and a high pH drives the reaction faster. Such information would give us an even deeper understanding of the benefits of biochar.

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Introduction

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Our project hopes to combat the rapid rise of greenhouse gas emissions by promoting a greener and safer way to fertilise one's soil. We hope that our experiments will comply with our hypothesis that the inclusion of a biochar coating will create a carbon sink, therefore reducing our CO^2 emissions and reduce ammonia emissions.

Protected Urea

Background information

Urea

With an N,P,K (nitrogen, phosphorus, potassium) ratio of 46-0-0, urea's nitrogen levels are greatly beneficial for soil health. Nitrogen (N), the most important of the macronutrients, is essential for sufficient plant growth. Therefore, farmers find the inclusion of high-nitrate fertilisers incredibly helpful. However, with its ever-growing popularity, more farmers are turning to urea-laced fertiliser, disregarding the release of toxic ammonia gasses into the atmosphere. If the soil the urea is being applied to is dry, there will be no reaction but if there is any moisture, the enzyme urease releases carbon dioxide and ammonia gasses into the atmosphere

Protected Urea

Protected urea is treated with an active ingredient called a urease inhibitor. This inhibitor is either incorporated into the urea granule melt during manufacture or coated onto the outside of the fertiliser granule, thus controlling the amount of ammonia released into the atmosphere. Urease is the enzyme which catalyses the conversion of urea to ammonia, resulting in the release of harmful ammonia gasses. However, the inclusion of a urease inhibitor impedes the reaction, resulting in a low level of ammonia lost; without losing any of its nitrogen, which is, in time, delivered to the crop. Another benefit to protected urea is that it prevents nitrogen from leaching into nearby water systems.

Biochar

Biochar is a carbon-rich substance made by burning organic material in a process called pyrolysis. It is produced to create a safe way to store carbon. It resembles a black, charcoal like substance. The material is very good for reducing greenhouse gas emissions and helps to retain nutrients in soil, so is therefore very useful for composting. It also helps to increase water retention, reduced nitrous oxide emissions, helps control nitrate leaching, improves structure of the soil and assists in decreasing the acidity of soil.

The biochar we used was supplied by Lough Derg Charcoal. It arouse from a Biomass to Biochar project, headquartered close to Mountshannon, which is a European Innovation Partnership (EIP) funded by the Department of Agriculture, Food, and the Marine (DAFM) under the Rural Development Programme 2014-2020. It is headed by Bernard Carey. The biochar he supplied us with was made from rushes, hazel and bracken.

Emissions

Ammonium indirectly contributes to greenhouse gas emissions. When ammonia enters the atmosphere, it combines with air pollutants (mainly nitrogen and sulfuric oxide compounds) from nearby vehicles, power plants and factories. This toxic amalgamation of gas can then travel long distances in the atmosphere. Here in Ireland, our agricultural sector is responsible for 99% of all ammonia emissions, putting farmers at risk to some of the many related illnesses. However, research has shown that protected urea gives around a 78% reduction in ammonia emissions compared to urea.

N,P,K

Soil nitrogen exists in three general forms: organic nitrogen compounds, ammonium ions and nitrate ions. At any given time, 95 to 99 percent of the potentially available nitrogen in the soil is in organic forms, either in plant and animal residues. However, the inclusion of urea boosts this. This nitrogen is not directly available to plants, but some can be converted to available forms by microorganisms. The majority of plant-available nitrogen is in the inorganic forms, ammonium ions and nitrate ions (sometimes called mineral nitrogen). Ammonium ions bind to the soils negatively charged cation exchange complex (CEC) and behave much like other cations in the soil. Nitrate ions do not bind to the soil solids because they carry negative charges, but exist dissolved in the soil water, or precipitated as soluble salts under dry conditions.

Aims

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- To see if different types of biochar would give different results.
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Experiment set up with ammonia detector showing

Methods

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Grinding down the Biochar into a fine powder

The next round of experiments we held were using 20g of urea and 15% biochar. We also experimented with 5% and 10% of biochar. We did this to see if we would get a faster result. We did seven experiments in this round, for each type of biochar. One out of each of the seven experiments was done using one of the faster ammonia gas detectors. Once more, we weighed out our urea (20g in this trial) and thoroughly coated them in a beaker using each of the finely ground biochar powders. We used 1cm of soil in a container and, to speed up our results, added 30ml of water to each container to ensure that there was enough moisture present. We watched these closely every day for 5 days and found that there was a much higher and quicker result than using the smaller measurements of urea.

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Set of experiments after being set up

Results

In our first trial, we ran 2 sets of 11 experiments, a total of 22 experiments running at a time. We had 3 types of biochar, each with a different percentage being used at a time (5%, 10% and 15%). Along with these we also ran 1 protected urea test and one normal urea fertilizer in each set.

Date	21-Nov
Hazel 5	0
Hazel 10	0
Hazel 15	0
Rush 5	300
Rush 10	200
Rush 15	150
Bracken 5	200
Bracken 10	200
Bracken 15	200
Urea	50
Protected	50

Results from Set 1 of the first trial

Date	21-Nov
Hazel 5	0
Hazel 10	0
Hazel 15	0
Rush 5	280
Rush 10	300
Rush 15	200
Bracken 5	220
Bracken 10	200
Bracken 15	200
Urea	100
Protected	50

Results from Set 2 of the first trial

We monitored these trials for 4 days and quickly realised that we had made a mistake in not taking into account the lack of moisture in the tubs because it was taking a very long time to get results.

In our second trial, we ran 7 treatments with 0.5g of biochar coated urea, for each type of biochar, 2 treatments of just urea, 1 treatment of just soil, 1 trial of protected urea and 1 treatment with 10% of each biochar. This was a total of 28 trials running at a time.

Date	Day 1	Day 2
Rush A	0	0
Rush B	0	0
Rush C	0	0
Rush D	8	10
Rush E	0	0
Rush F	0	0
Rush G	0	10

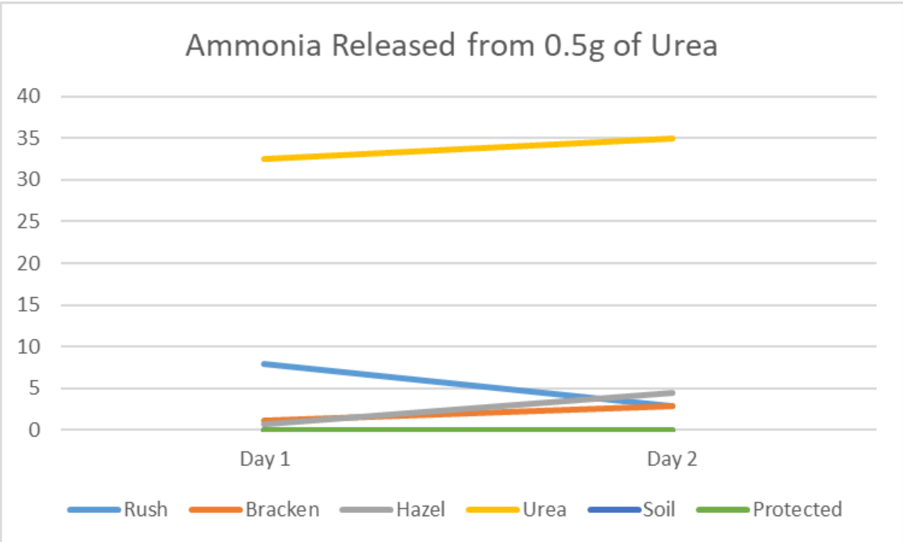
	Day 1	Day 2
Bracken A	0	0
Bracken B	0	10
Bracken C	0	0
Bracken D	8	10
Bracken E	0	0
Bracken F	0	0
Bracken G	0	0

	Day 1	Day 2
Hazel A	0	25
Hazel B	0	0
Hazel C	0	0
Hazel D	5	6
Hazel E	0	0
Hazel F	0	0
Hazel G	0	0

	Day 1	Day 2
Urea	40	40
Urea 2	25	30
Soil	0	0
Protected	0	0
Hazel 1g	50	50
Rush 1g	50	50
Bracken 1g	30	30

The above tables are the results we got for each of the experiments we did in this trial.

	Day 1	Day 2
Rush	8	2.857
Bracken	1.143	2.857
Hazel	0.714	4.429
Urea	32.5	35
Soil	0	0
Protected	0	0



This is the average amount of ammonia that was released from each of the experiments over a period of two days.

These results still took a long time to show up so we decided to do a trial with a larger amount of urea in the hopes of getting a quicker result. It contained 20g of urea and 15% biochar. We did 7 of these experiments for each type of biochar. We also did 2 5% and 2 10% biochar trials for each one, 2 just with urea, 1 with just soil and 1 with protected urea. This was a total of 31 experiments running at a time. One of each of the experiments with the biochar coated urea, we used a faster gas detector to see if the results would differ.

Date	1 Day	2 Days	3 days	4 days	5 days
Rush A	20	140	340	510	Full
Rush B	20	110	300	500	Full
Rush C	20	100	300	475	Full
Rush E	50	190	390	550	Full
Rush F	40	120	390	550	Full
Rush G	50	210	430	600	Full

20g of Urea Coated with Rush Results.

Date	1 Day	2 Days	3 Days	4 Days	5 Days
Bracken A	0	80	200	370	540
Bracken B	10	100	290	425	600
Bracken C	25	130	300	500	Full
Bracken E	30	140	400	550	Full
Bracken F	50	190	400	600	Full
Bracken G	0	70	220	400	550

20g of Urea Coated with Bracken Results.

Date	1 Day	2 Days	3 Days	4 Days	5 Days
Hazel A	40	90	390	550	Full
Hazel B	40	90	390	520	Full
Hazel C	20	100	110	200	300
Hazel E	25	120	320	500	Full
Hazel F	20	170	400	550	Full
Hazel G	20	110	400	510	Full

20g of Urea Coated with Hazel Results.

Date	1 Day	2 Days	3 Days	4 Days	5 Days
Rush 10%	10	120	310	525	Full
Hazel 5%	50	180	320	500	Full
Rush 5%	10	110	340	550	Full
Hazel 10%	25	120	360	550	Full
Bracken 5%	0	25	100	200	380
Bracken 10%	0	10	100	270	480

20g of Urea Coated with either 5% of 10% of each Biochar Results.

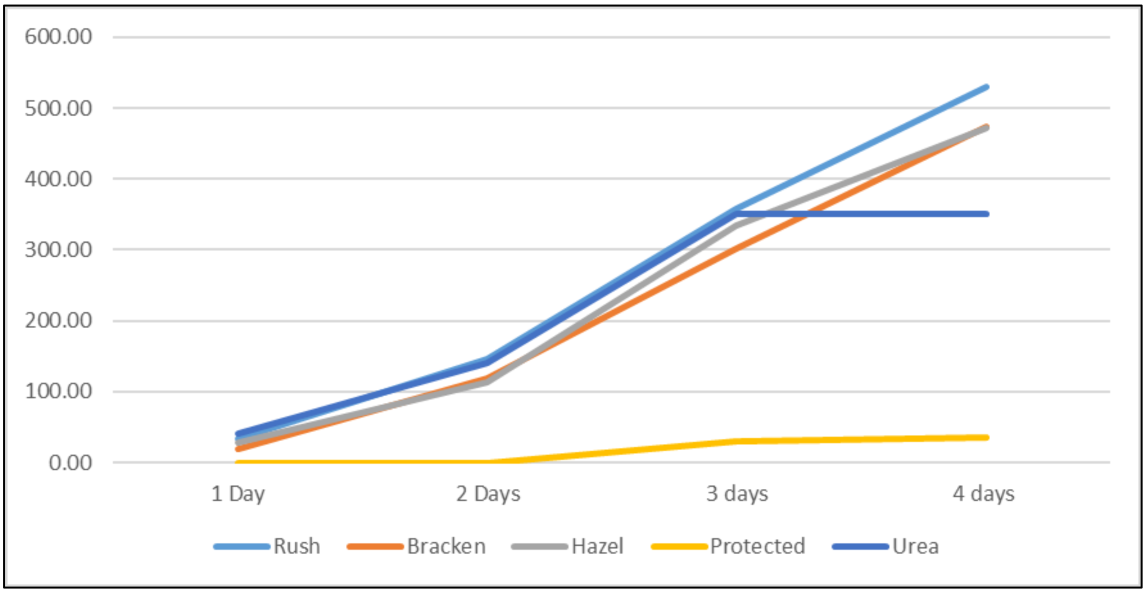
Date	1 Day	2 Days	3 Days	4 Days	5 Days
Urea	40	130	250	500	
Soil	0	0	0		
Protected	0	0	30	40	50

The other experiments in our trial.

Bracken D	15
Rush D	8.5
Hazel D	9
Urea 2	10

These were the results for the experiments that had the faster ammonia gas detectors in them. We got this result after five days of observing them.

	1 Day	2 Days	3 days	4 days
Rush	33.33	145.00	358.33	530.83
Bracken	19.17	118.33	301.67	474.17
Hazel	27.50	113.33	335.00	471.67
Protected	0.00	0.00	30.00	35.00
Urea	40.00	140.00	350.00	350.00



These are the averages of the ammonia gas released from each of our experiments in this trial.

The final trial we did was with 5g of urea fertiliser and 15%, 10% and 5% of biochar. We did 6 experiments for each type of biochar with 15% of it, and two of 5% and 10% for each one also. We also did 3 regular urea experiments, 3 soil and 1 protected urea experiment, which was a total of 37 experiments running at the same time.

		Day 1	Day 2	Day 3	Day 4
Urea 1		50	130	220	340
Urea 2		40	130	240	300
Urea 3		50	110	210	290

Results from the plain urea trial.

The 3 soil trials we did all came back with a reading of 0 ammonia being released from it after five days.

		Day 1	Day 2	Day 3	Day 4
Protected		0	0	25	40

Results from 5g of protected urea.

Date		Day 1	Day 2	Day 3	Day 4
Bracken	A	25	140	220	310
Bracken	B	25	100	190	250
Bracken	C	25	110	200	250
Bracken	D	40	110	200	220
Bracken	E	20	110	190	250
Bracken	F	20	100	150	200
Bracken	5% 1	0	100	180	250
Bracken	5% 2	0	90	160	220
Bracken	10% 1	0	90	120	190
Bracken	10% 2	0	50	150	210

Results from 5g of urea coated with bracken biochar.

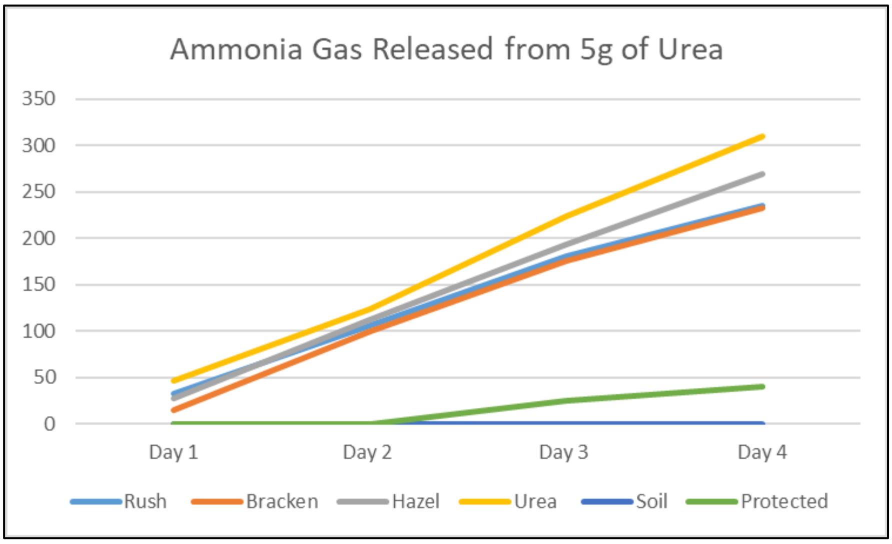
		Day 1	Day 2	Day 3	Day 4
Rush	A	40	110	200	280
Rush	B	20	100	190	250
Rush	C	50	190	250	340
Rush	D	20	100	180	210
Rush	E	30	70	110	190
Rush	F	40	100	180	210
Rush	5% 1	50	100	190	220
Rush	5% 2	30	90	140	200
Rush	10% 1	20	100	180	210
Rush	10% 2	20	100	180	210

Results from 5g of urea coated with rush biochar.

		Day 1	Day 2	Day 3	Day 4
Hazel	A	40	140	220	300
Hazel	B	20	90	150	300
Hazel	C	25	120	210	300
Hazel	D	40	150	230	300
Hazel	E	45	120	210	290
Hazel	F	50	100	180	210
Hazel	5% 1	10	100	150	250
Hazel	5% 2	10	100	200	240
Hazel	10% 1	20	100	180	220
Hazel	10% 2	10	100	200	280

Results from 5g of urea coated with hazel biochar.

	Day 1	Day 2	Day 3	Day 4
Rush	32	106	180	235
Bracken	15.5	100	176	232
Hazel	27	112	193	269
Urea	46.7	123	223	310
Soil	0	0	0	0
Protected	0	0	25	40



The average results of the ammonia gasses released from 5g of urea.

Discussion

Upon reflection, we realise that we made a mistake in not taking the lack of moisture in the containers into account when doing our first trial of the experiment. We rectified our mistake when we were in contact with Patrick Forrestal and he told us that we need to have some sort of moisture for the results to happen.

We adapted our other experiments with this knowledge. We didn't get the results we had hoped for but we think our project is a step in the right direction to make Irish agriculture practices more environmentally friendly. We know that charcoal absorbs gasses but there is a certain limit to how much it can hold, which could be why we saw a slower release of ammonia gasses at the start of our trials.

We also know that biochar is a carbon sink so would be very beneficial in soil to help combat carbon emissions. We saw the results of the experiments vary slightly which could be down to the difference in size of the granules of urea. All of our trials were kept in the exact same conditions, the same measurements were used throughout and the same equipment was always used.

Conclusions

Our first aim was to see if coating urea with different amounts of biochar would reduce the release of ammonia by urea. From our investigations we can see that biochar did not reduce the release of ammonia by the urea. We can see that the biochar coated urea released less ammonia gas at the start of the trials compared to the regular urea, but by the end they caught up with each other. We think that this might be because charcoal does absorb some gasses, but can only hold a certain amount.

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Beat the rush with sustainable farming project in Clare
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Acknowledgements

Firstly, we would like to thank our school for allowing us to take part in the BT Young Scientist Exhibition. We would like to thank Ms.Hynes for allowing us to use the school during the Christmas holidays so we could do practical work on our project.

We would also like to thank the BTYSTE team for selecting our project to go through and giving us this great opportunity.

We are incredibly appreciative of our parents who drove us to and from the school so we could work on our project.

We would like to thank Patrick Forrestal from Teagasc, who supported us throughout our project and was there to offer his expertise when we needed it.

We would also like to give thanks to Bernard Carey from Biomass to Biochar, who supplied us with the biochar we needed for our project.

Finally we would like to thank our teacher Mr. Sims who took the time to help and encourage us with our project; it wouldn’t have been possible without him.