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ARTICLE

Grassheet: A Sheet of Grass

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Regional level gold medal with four sponsorship awards. National level silver medal, won challenge award in the natural resources division

Classrooms use significant amounts of paper on a daily basis, and even more is thrown out. As the human population continues to grow, more homes are built but at the cost of ecosystems, habitats and agricultural fields. With every house built there are trees cut down, therefore, I wanted to find an alternative to wood paper products as trees are being deforested at an alarming rate. Through experimentation, I was able to utilize mowed grass clippings to make paper out of grass. For the first three trials, I used a similar method to how homemade paper is made; however, grass clippings fell when the paper was moved. I then researched how paper is made commercially and found that chemicals are used. One of those chemicals is washing soda, and through the utilization of this chemical the cellulose fibers at a molecular level broke down to produce a smoother surface, legible to read.

INTRODUCTION

Every second a forest the size of a football field is cut down. Every minute 2,400 trees are cut and every year a forest the size of Switzerland is lost (Toner Buzz [TB], 2022). Deforestation does not only affect forests, but the loss of trees contributes to polluting the environment as pulp and paper are the third-largest industrial polluters of air, water, and land in North America (Watershed Sentinel, 2012). Paper production is the world's fifth-largest energy consumer (Ellen, 2016). Additionally, the pulp and paper industry exploits more water compared to other industries; however, this statistic does not include the amount of water needed for a tree to mature (TB, 2022). Trees will consume 0.0379 cubic meters of water for every 2.5 centimeters in diameter (Arbor Day Foundation [ADF], 2018).

Depending on the species, trees can take on average 15-30 years to grow (Green Pine Tree Service [GPTS], 2020). Whereas grass takes about three to four weeks to be long enough to mow (Grass Master, n.d.). Additionally, it takes 24 trees to make one thousand kilograms of paper, which is about 200,000 sheets (Oregon State University [OSU], 2021). Manufacturing plants also emit nitrogen dioxide, sulfur dioxide, and carbon dioxide, which are significant contributors to acid rain and the greenhouse effect (Mace, 2015).

Another overlooked dilemma that negatively affects the environment is the accumulation of grass clippings in landfills. During the peak growing season, grass clippings can amount to almost 50% of all waste materials collected (Don't Trash your Grass, 2014). As grass clippings decompose in landfills, the leachate that is created through the grass clippings contribute to groundwater contamination affecting ecosystems (How to Compost Grass, 2014).

How can we reduce deforestation and utilize already thrown away grass clippings to save the environment? Likewise, can grass clippings be used as an alternative fibre in the production of paper products? This experiment aims to answer if grass clippings can be used as a sustainable and practical alternative without compromising the texture, thickness, and legibility of manufactured letter paper.

MATERIALS & METHODS

I had done a total of eleven trials, adapting the procedure to experiment to what extent can paper be made from grass. At the beginning, I was not aware that a chemical would be needed to break down the cellulose fibres at a molecular level. By using washing soda, the texture of the paper changed dramatically as the paper yielded a smoother surface. In the same way, I thought the mould and deckle would increase the efficiency of the procedure, however, the lightweight qualities of the trial produced tissue paper rather than writing paper.

For the first three trials, I used a similar process to homemade paper by following a YouTube video as my reference (Vijayta, 2020). I used the same steps but boiled the grass fiber until bubbles formed. At first, I was content to stop at this stage as I had made paper out of grass; however, my vice principal suggested going quality over quantity. For the subsequent trials, I adopted chemical techniques used in pulp and paper factories to see if it would help reproduce the texture, thickness, flexibility and legibility of wood paper.

I found that chemicals are used to break down wood fibres at a molecular level. One of the hundreds of chemicals used in paper production is caustic soda (Brennan, 2018). Caustic soda is a common ingredient in laundry detergents and can easily be made at home from baking soda (Gippsland Unwrapped [GU], 2016). Washing soda, which is baking soda baked at high temperatures, is the common name for sodium carbonate (PCC Group Manufacturer of Specialty Chemicals [PCC GMSC], 2021). Sodium carbonate is considered eco-friendly since it occurs in nature in its dissociated form (PCC GMSC, 2021). For this reason, I had chosen washing soda to break down the cellulose fibres in grass clippings as it does not harm living organisms if the paper were to come in contact with them.

For the fourth trial, I used two tablespoons of washing soda,

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boiled then simmered the mixture for 90 minutes and blended the pulp for one minute. These differences made a significant difference in the end result of the paper as it was smooth and legible like manufactured paper. It was quite difficult for me to contain the pulp within the oil splatter sieve because it did not have a barrier to stop the pulp from floating away in the water. With the help of my teacher, we built a mould and deckle (used to make professional homemade paper) as a possible solution. However, the fifth and sixth papers made from the mould and deckle have a similar texture to tissue paper due to their thinness, transparency and light weight qualities.

The purpose of the seventh and eighth trial was to test run the materials and to time the procedure before the field trip (I had taken a class of fifth grade students to the science lab where they made their own Grassheet's from scratch). The next day, the students got to color and personalize their own papers and when they finished I compiled their works into a book (the ninth trial). The papers of the students were flat compared to my seventh and eighth trial because they spent a longer time soaking up excess water. Since I was timing myself, I had neglected the importance of soaking as much water as possible, hence the slight bumpiness in trial seven and eight.

The tenth and eleventh trials are from the same batch as I had split it up to test the effects of using hydrogen peroxide as a natural bleaching agent. As a result, the eleventh trial had a slight yellowish hue.

RESULTS

I did a total of eleven trials starting from the beginning of December to the end of April. The procedural differences between each trial as well as the pros and cons are described in more detail in Table 1. The first three trials did not have a similar texture to manufactured paper as grass clippings would get in the way. However, the fourth trial was smooth enough to write on and as thick as a piece of paper. With my teacher's help we built a mould and deckle which was used for the fifth and sixth trial. Due to the inconsistencies in texture, the fifth trial cannot be easily written on because I had poured the diluted pulp mixture on top resulting in inconsistencies since there was no solvent to make the fiber uniform. The sixth trial was submerged completely under water and hence the smoothness and consistency of the paper. Despite this, the sixth trial is as thin as tissue paper and is difficult to write on without creating holes in the process. The seventh, eighth and ninth trial have a slight bumpiness in texture however they still provide a smooth surface that is legible. The tenth and eleventh trial was made from the same batch but were split to test if hydrogen peroxide can bleach the grass fibre. The eleventh trial was soaked for 12 hours in hydrogen peroxide to bleach the paper, resulting in a slight yellowish hue, resulting in a slight yellowish hue. All trials after the fourth are similar if not identical in texture as shown in Figure 1; they are all eligible to write on since they have a smooth surface and the same thickness as manufactured letter paper.

DISCUSSION & CONCLUSION

Around the world, paper is primarily made from cellulose fibres (1.1-Production/consumption, n.d.). Less than two thirds of paper products come from wood, one third from recycled paper and roughly 5% from non-wood sources (1.1-Production/consumption, n.d.). Therefore, by making paper out of grass it reduces the dependability of wood fibre in the pulp and paper industry. As a result, this experiment proves that grass clippings can be an alternative to wood paper products without compromising the texture, thickness, legibility, and flexibly of wood paper. The fourth, seventh, eighth, ninth and tenth trial show that grass clippings have a similar texture to office paper. On the other hand, the trials made with the mould and deckle resulted in a texture similar to tissue paper.

The potential of grass paper products are endless and can have a significant impact on the environment by reducing one third or more of trash created by the packaging industry (Paper Waste Facts, n.d.). Grassheet is a sustainable, easily accessible, and inexpensive alternative to wood paper products because it tackles two problems in one: reducing deforestation and utilizing grass clippings from landfills. Whether the grass is freshly mowed or is left to dry it does not affect when Grassheet can be produced. Likewise, it will not slow down a company's production rate since the grass clippings can be utilized any time of the year just like trees (Sustainably Harvesting Trees in the Winter, n.d.). Additionally, companies can utilize the community's mowed grass clippings as an inexpensive but practical source. By making use of already thrown away grass clippings, companies do not need to spend a fortune in planting and harvesting trees. Not only is Grassheet cheaper because it reuses waste, but it is also simpler in the manufacturing process and does not require multiple processes taking place in several warehouses. As a result, Grassheet will be time and cost effective without compromising the health of the environment.

Grassheet is not limited to being a science fair project but is a proposal for companies to adapt in the future. Furthermore, the field trip reinforces the simplicity of using grass clippings as students can easily replicate it in a school laboratory. On top of that, Grassheet can reduce greenhouse emissions and deforestation, making the world better, cleaner, and healthier.

NEXT STEPS

I would like to make Grassheet a reality by scaling it up to be manufactured by pulp and paper companies. By experimenting with the thickness of the paper, the products of Grassheet are endless, from writing paper to food containers to newspapers. On a larger scale, I would also like to experiment with methods to reduce drying time but maintain a similar energy consumption level to increase production efficiency. I would also like to experiment if the concentration of hydrogen peroxide will whiten the paper completely white as opposed to a slight yellowish hue.

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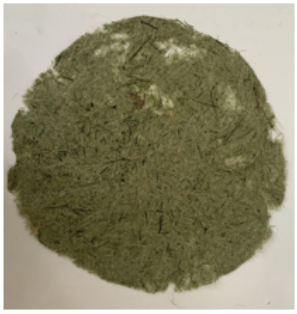
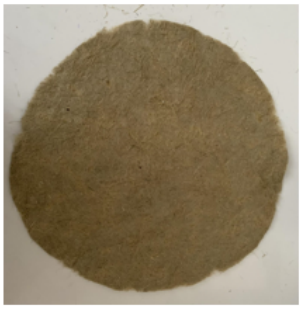
Figure 1: shows all eleven trials starting with the first on the left side ending with the eleventh trial on the right. Please note that the eighth trial was used in the book.

Table 1: Procedural differences and notes for each trial

Trial #	Picture	Procedural Differences	Notes
1		- used fresh green grass and dried for five days even though it was dry by the third - boiled grass for 20 minutes - used oil splatter sieve - used homemade paper method	- the color of the final product is green - took 16 hours to dry
2		- used yellow grass (this is what I had found in my neighborhood) - same procedure as trial one but blended the pulp for longer and added water to the blender - filled in as many holes as I could by taking scapes of grass pulp to cover the holes resulting in a thicker sheet - boiled grass for 20 minutes - used oil splatter sieve - used homemade paper method	- the color of the final product is yellow - took 16 hours to dry
3		- no holes in final product - used a third of the quantity of trial one/two to make one thicker sheet of paper - used more water in blending and blended for a longer time - used oil splatter sieve - used homemade paper method	- took 16 hours to dry

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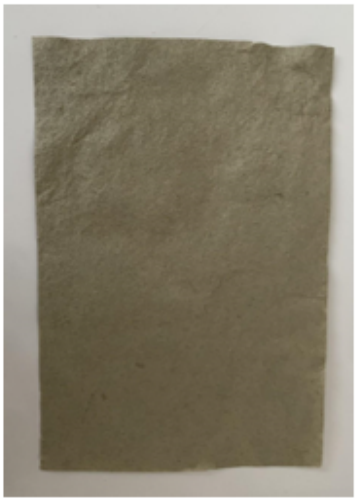
4		- made two sheets on a towel and another on a sieve - grass was cut into smaller pieces before soaking overnight - used 3 tbsp of homemade washing soda - boiled grass clippings for an hour - filled blender with water, grass clippings and empty space with a ratio of 2:1:1 - blended for a total of three times for 40 seconds each to use up cooked grass - used oil splatter sieve -used manufactured paper method	- the sheet of paper on the sieve dried in less than 6 hours - papers on the towel took 24 hours to dry
5		- did not have a large enough container to submerge mould and deckle in water so blended pulp was poured on top of mould and deckle - even with the slight decrease in washing soda the pulp still blended easily - used the same procedure as trial four with the same quantities - used 2 tbsp of washing soda instead of 3 -used mould and deckle -used manufactured paper method	- took about 6 hours to dry
6		-used mold and deckle - found a large enough container to fit mould and deckle -used manufactured paper method	- took about 6 hours to dry

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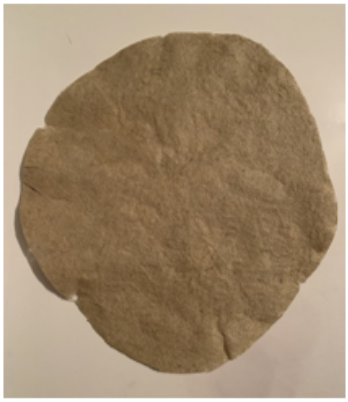
7		- used the materials for the field trip to test run it for students - made an aluminum foil 'barrier' to cage in the diluted pulp - used 2 tbsp of washing soda with 2 cups of dried grass (measurement is before soaked overnight) -used manufactured paper method	- this trial was given to a student - after a few times the metal 'barrier' fell apart because the aluminum foil got soaked with water - took 16 hours to dry
8		- used the materials for the field trip to test run it for students - used 1 tbsp of washing soda with 2 cups of dried grass (measurement is before soaking overnight) - slightly submerged sieve into water - the pulp evenly coated the sieve in the water the first time so the metal 'barrier' did not have time to fall apart - used a sponge to soak up as much water as possible -used manufactured paper method	- this trial was used as the cover of the student book - took 16 hours to dry
9		- used the same procedure as trial eight with the same materials - each group had 300g of already soaked overnight grass - each group used a total of 5 tbsp of washing soda -used manufactured paper method	- field trip with grade five students - 20 students participated with six groups - some students wanted their paper to be small hence the various differences in size - took 16 hours to dry

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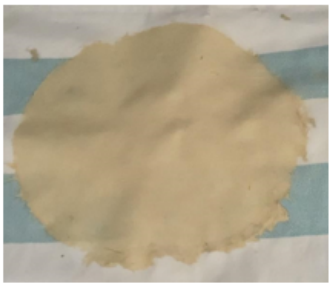
10		- continued the same procedure as previous trials - accidentally diluted pulp with too much water resulting in the paper to be thin - used 245g of grass clippings (measurement is taken after soaked overnight) - used less water than previous trials in bucket of container to reduce water usage -used manufactured paper method	**for trial ten and eleven they were made from the same batch but were separated into two bowls after blending - made a total of 5 sheets of paper
11		- used hydrogen peroxide to 'bleach' paper - did not use too much water to dilute pulp hence the no holes - used less water than previous trials in bucket of container to reduce water usage -used manufactured paper method	**for trial ten and eleven they were made from the same batch but were separated into two bowls after blending - made one sheet of paper

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Table 2: Smoothness, flexibility, pros and cons for each trial

Trial #	Smoothness	Flexibility	Pros	Cons
1	- can write on but not that easily - flat - grass clippings will get in the way of writing	- fragile - thin - can fold	- can write on it - easy to remove from towel - easy to cut and reshape with scissors	- holes in finished product - grass clippings fall as the paper is moved - writing is not that clear but is visible - not as smooth as manufactured paper - thickness is the same as manufactured paper - can slightly see pen/marker on back side
2	- can write on but not that easily - flat - grass clippings will get in the way of writing	- less fragile - thicker than trial one - can fold	- can write on it - yellow is easier to see when writing on it - writing is clearer - smaller holes - easy to remove from towel - less fragile than trial one since there are less holes - easy to cut and reshape with scissors	- grass clippings fall as the paper is moved - still not as smooth as manufactured paper -slightly thicker than manufactured paper - there are holes in the finished product - can slightly see pen/marker on back side

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3	- can write on but not that easily - flat - grass clippings will get in the way of writing	- holds its shape - thick - can fold	- no holes - smoother to write on than trial 1 and 2 - writing is as clear as trial 2 - cannot see pen/marker on back side - easier to see writing on yellow - easy to remove from towel - easy to cut and reshape with scissors	- grass clippings fall as the paper is moved - still not as smooth as manufactured paper - thicker than manufactured paper
4	- very smooth to write on like wood paper - flat - no grass clippings get in the way of writing	- holds its shape - same thickness as wood paper - can fold	- lighter green than trial one - no holes - smooth to write on - writing is legible - cannot see pen/marker on back side - easy to cut and reshape with scissors - easier to remove papers from towel than directly from sieve - same thickness as manufactured paper - can use tape on it without tape falling off	- took a long time to gather pulp and shape it when the sieve is submerged in water

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5	- can write on but some parts have bumps so not as smooth as trial 4 - flat - can see pen/marker on back side - no grass clippings get in the way of writing	- slightly fragile but holds its shape - thin like tissue paper - can fold	- thinner in thickness than manufactured paper (excluding thicker parts) - easy to cut and reshape with scissors	- inconsistencies in texture - pouring directly on top without water resulted in inconsistencies as the pulp clumped together - texture is smooth in some places, thicker in others or has holes
6	- very smooth to write on but do not recommend because paper is very thin - flat - no grass clippings get in the way of writing	- fragile but holds its shape - thin like tissue paper - can fold	- texture is similar to tissue paper - can write on it - mould and deckle contained the grass clippings much easier than the sieve - consistency in texture - thinner in thickness than manufactured paper - easy to cut and reshape with scissors	- better to use as tissue paper because of its thinness and pen/marker will show on back - had difficulty removing paper from mould and deckle so a knife was used to remove it hence the little holes in the final product - it is tedious to remove paper from mould and deckle compared to the towel

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7	- very smooth to write on like wood paper - bumpy - no grass clippings get in the way of writing	- holds its shape - same thickness as wood paper - can fold	- writing is legible - no holes - smooth to write on - cannot see pen/marker on back side - easy to cut and reshape with scissors	- submerged pulp into the water multiple times leading to the metal 'barrier' falling off and holes to form in the end product - paper is not flat (used a different, thinner towel which lifted as the water evaporated from the grass hence the slight bumpiness)
8	- very smooth to write on like wood paper - slightly bumpy - no grass clippings get in the way of writing	- holds its shape - same thickness as wood paper - can fold	- writing is legible - no holes - smooth to write on - paper is flatter than trial seven but has a slight bumpiness - cannot see pen/marker on back side - easy to cut and reshape with scissors	- there is still a slight bumpiness since the same towel was used as trial 7 but more time was spent in soaking up excess water

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9	- very smooth to write on like wood paper - flat and not bumpy - no grass clippings get in the way of writing	- holds its shape - same thickness as wood paper - can fold	- the majority were smooth and flatter than trial 7 and 8 since the students used sponges to soak up as much water as possible - drawings were legible and clear (even yellow was visible) - easy to cut and reshape with scissors - for the majority of papers cannot see pen/marker on back side	- results varied in having holes or not - some had holes
10	- very smooth to write on like wood paper - flat and not bumpy - no grass clippings get in the way of writing	- holds its shape - a little bit fragile - same thickness as wood paper - can fold	- can write on it - less water was used in container and did not negatively affect submersion of sieve (only need the surface of the water to loosen fibres but too much water makes it difficult to contain pulp) - easy to cut and reshape with scissors	- slightly thin - has small holes because of too much water used to dilute the pulp before pouring over sieve
11	- very smooth to write on like wood paper - flat but slightly bumpy - no grass clippings get in the way of writing	- holds its shape - same thickness as wood paper - can fold	- can write on - easy to cut and reshape with scissors	- takes 12 hours for pulp to become white - highest concentration of hydrogen peroxide found is 3%

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Rawaan Mohamed Said Mohamed Ibrahim, and yes that is her full, real name :), is an Egyptian born Canadian Muslim. Her favorite food is chocolate, and she believes in eating dessert every single day. Hence her passion for baking healthy, homemade desserts. She enjoys DIYing her school supplies and building new things that can help those around her. Thus the reason for her innovative initiative of making paper out of grass aka Grassheet.

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