BrownWoods & Associates Inc.

Final Report

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ENVS 492
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Executive Summary

Our team, made of Anne, Elaine, Elliot, Shreya, and Shreeya has been working with Paul Littleton from the BrownWoods & Associates landscaping company in order to help him find the optimal amount and type of herbicide that can be used to control weeds in the field. We determined the efficacy of synthetic and organic herbicide mixtures with varying concentrations in controlling and killing weeds to minimize unnecessary usage. The experiment was conducted in Champaign, IL at the BrownWoods & Associates location. Running for a total of 5 weeks, from mid-September to the end of October. Our goal was to minimize the negative impacts that the overapplication of herbicides has on the environment. To achieve this we created a series of plots treated with various herbicide mixtures and compared those plots with each other and to untreated control plots. We performed a visual analysis and comparison to understand how effective each mixture of herbicides is against our identified invasive species of various broadleaves and grass species.

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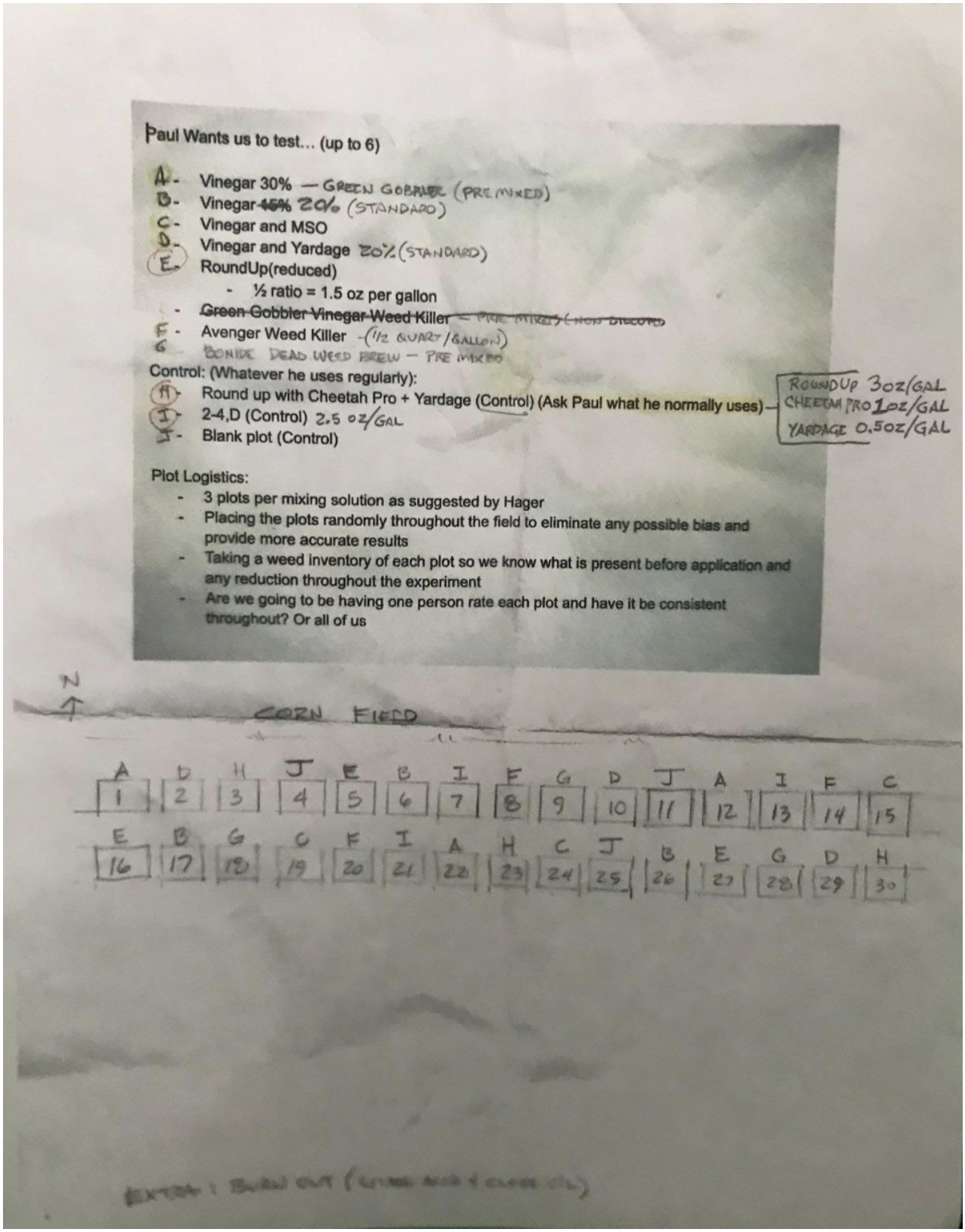

Figure 1: The above image created by Paul from Brown Woods Landscaping shows the layout of plots for our experiment, as well as the different mixtures used.

Project Description, Objectives, and Scope

For this project, we have set out to help Paul Littleton, a landscape architect at Brown Woods & Associates Landscaping Company, keep unwanted weeds off of his land. He has asked us to determine the least amount of herbicide that can be used in order to effectively remove the creeping charlie (broadleaf weed species), fox tail grass, clover (broadleaf weed species), dandelion (broadleaf weed species), and plantain (broadleaf weed species) in his field without compromising the integrity of the surrounding environment, or ruining the fescue grass in the field.

Before beginning this project, we went to visit the Brown Woods landscaping company in order to observe the land area that we would be working with. Then, we set up our experiment by marking out 30 plots, each plot being 3x5 feet. Using the pre-existing herbicides in the Brownwoods inventory and our background knowledge of these herbicides and their effects, Paul Littleton and our team came up with 7 different mixtures to test, and sprayed each plot with a different mixture, making sure to keep 9 control plots: 3 blank plots, 3 plots with Paul's usual mixture of Roundup with Cheetah Pro and Yardage, and 3 Plots sprayed with 2-4 D (2.5oz/gal as per Paul's normal mixture). The different mixtures that we used for this experiment are as listed in the image above, Vinegar 30% - Green Gobbler (Pre-Mixed), Vinegar 20% (Standard), Vinegar and MSO, Vinegar and Yardage 20% (standard), Roundup (Reduced - ½ ratio = 1.5 oz per gallon), Avenger Weed Killer (½ quart/gallon), and Bonide Dead Weed Brew (Pre-mixed).

Every plot was divided into two halves: the east half and the west half. Then, the mixture was sprayed onto three different plots, with each plot having a reapplication of this herbicide mixture placed on the east or west half of the plot. At the start of our experiment, we kept a weed inventory to keep track of how many weeds were in the plots and compared this number to the number of weeds remaining at the end of the experiment. Throughout the course of the 5 week experimentation period, BrownWoods crews applied the herbicide once every two weeks and made sure to take pictures of the plots after each week in order to capture the changes that occurred throughout the experiment.

At the end of our experiment, we made a trip to Brown Woods landscaping company as a group and surveyed the plots, using a rating scale of 1 (poor) to 5 (great) to rate how well each herbicide did in removing the weeds from the grass. Our second survey was done virtually, using each set of images we took of the plots after each week. Not only did we rate the herbicide's impact on the weeds, but we also kept track of color changes in the plots by laying a grid over the images in Photoshop and highlighting the areas that remained green, and turned brown. After obtaining this data we used it to create different graphs and charts that show us how well each herbicide did in comparison with the controls we set up. In this project, we considered weather events such as rain and wind to be extraneous.

Barriers and Scope Adjustment

In order to keep track of the herbicide's effectiveness, we took pictures of the plots week by week, laid a grid over these images, and highlighted the green and brown areas of the plots. We then interpreted the brown and green portions of the images, assuming that the lower the green portions on the images, the more effective a herbicide mixture is. This interpretation caused issues in our final calculations, as living weeds that had not been impacted by the herbicide remained green, while damaged fescue grass turned brown. Rather than highlighting parts of the images that were green or brown, we should have identified living weeds and dead weeds in order to strictly keep track of the herbicide's effectiveness. Doing so would have helped us keep track of how effective the herbicide was in removing weeds, as our main priority was to make sure that the herbicide eliminated weeds, not the grass specifically.

We also did a second set of ratings virtually based on the pictures that we had taken while we were at Brown Woods, and in these images, we did not use a marker to indicate which side was east or west. Because of this, we assumed that the east was on the left side, which could have negatively impacted our final results. It is also quite possible that our virtual ratings of the herbicide’s effectiveness may have been less accurate than our in-person ratings, as we were not able to use our hands to move the grass aside and look for wilted weeds for our virtual ratings. During one of our in-person visits, a video of the plots was taken by accident, rather than still photographs of the plots. To overcome this issue we took screenshots of the plots from the video that was taken and used these screenshots to help complete our objective.

Research Methods Process

There were several stages in our project with Brown Woods that required different research methods. A significant component of our project at the beginning stages was to find non-synthetic herbicide alternatives to be tested against the common synthetic herbicides used by Brown Woods and the industry as a whole. In order to make sure that BrownWoods is using the most relevant and useful information, we used only the most trustworthy sources we could locate. Some of our key resources used included Google Scholar, published scientific papers, as well as reaching out to experts from the University.

The team comes from different areas of study and none included herbicide usage and weed science. Due to this, we had to immerse ourselves in the world of weeds. Our scientific backgrounds assisted in formulating a proper experiment given the goals we had at hand. In addition, it helped us grasp the concepts and common practices regarding herbicide use within the industry sector.

The selection of targeted weeds came from the recommendation of our partner liaison Paul Littleton. Upon meeting, he told us the weeds Brown Woods come across the most. These

included perennials such as Glechoma hederacea (better known as creeping charlie) and clover, broadleaves such as dandelion and plantain, and grasses such as foxtail. Stated interest in these five weeds is why we chose them as the area of focus.

Regarding reaching out to experts on the campus of the UIUC we namely reached out to Professor Aaron Hager in the crop sciences department. His area of focus and research has been weed science and treatment options. The team met with Professor Hager prior to finalizing our experiment design, but after having done the initial research and a rough mockup of the setup. Professor Hager confirmed that we should designate each solution three plots and have incorporated randomization in the placement of the plots. This was to assure a proper amount of data would be collected and the reduction of human bias. Hager told us that most studies created on the subject of herbicide use on weeds are often meant in an agricultural sense, therefore yield is a big component to be incorporated in the grading process. However, this was an aspect we did not need to include. BrownWoods is not focused on the agricultural implications of herbicide use, but on residential and commercial building zones. We were not going to account for any loss of yield due to herbicide use because our goal was to eliminate weeds for aesthetic purposes, ergo remove weeds that have encroached or are encroaching on landscaping. Additionally, we were given insight into rubrics for ratings done in past experiments by Professor Hager regarding herbicide efficacy. This assisted in the crafting of the weed rubric created that will be discussed in greater depth when discussing our analysis methods.

The experiment was conducted on-site at BrownWoods & Associates in Champaign, Illinois. Thirty 3’ x 5’ plots were set up in two rows, fifteen plots in each row, each plot divided in two, one side for a single application and the other for two applications of the same mixture. The chosen form of analysis media was pictures, the team went weekly to the site to take pictures of each plot in order to track progress. As well as an in-person weed rating at the end to search for any surviving weeds within a plot, and a weed rating done from the pictures taken at the midpoint of the experiment.

Our final result is based on two data sets: plot rating and green percentage calculations for each plot. We developed a grading template based on Professor Aaron Hagar's recommendations and an Iowa State University Extension publication (*Soybean Herbicide Effectiveness* Ratings, 2005) on soybean herbicide efficiency rating on grasses, broadleaves, and perennial weeds. The plot was scored on a scale of 1 to 5, with 1 indicating poor herbicide performance and 5 indicating good performance. We requested Paul and Gwen to rate the final results in addition to other team members scoring the plots for the middle and end of the experiment. This was meant to diversify the ratings, so all were not coming from our team alone, and include ratings from those with a more experienced eye.

The calculation of green percentages began with organizing and tilting the site photographs in Adobe Photoshop to ensure consistency. After that, the photographs were resized in AutoCAD, and 3" grids were applied within the boundary, creating 240 pixels for each plot. Then, in Photoshop, we highlighted the pixels that remained green at the 150% zooming level for every plot. In order to minimize subjectivity and inaccuracies in the process, we assigned two

members to analyze the images individually for each date photos were taken. Following that, we averaged the percentages of the two members and compared those throughout the experiment. This was to track any changes in the coloring of the plot from week to week.

Both of our analysis methods were taken into consideration when deeming which herbicides were the most successful in eliminating our selected weeds of interest. Below you will find a weed inventory created by the team. Each plot and its varying sides of east and west were observed through the available photos taken prior to any application. For each weed, a rating between zero and three was given, with the number of weeds located in the given area next to this number. Zero or N/A indicated the weed was not present, one meant 1-3 were present, two was 4-6 weeds present, and three was anything above 7 weeds present. We intend this weed inventory to be used as a point of reference for those looking to recreate our experiment and or gain a deeper understanding of the targeted weeds and their interactions with different herbicides. In more depth, the tool can be used to cross-reference any weeds that proved to be resistant to specific herbicides or those that showed little to no immunity.

ENVS492 -- Herbicide effectiveness ratings

Weed response to select herbicides **(0 = 0, 1= 1-3 2= 4 - 6 3 = 7+ , N/A)**

Plot #	Grass	Broadleaves		Perennials		Overall aesthetics	
	Foxtail	*Dandelion*	*Plantain*	*Creeping charlie*	*Clover*	*Comment box*	*Reapplied*
1	N/A	N/A	2 : 5 plantain present	N/A	3 : more than 30 clovers present		reapplied
2	1: 2	2 : 6 present	2 : 5	N/A	3: 100 + clovers	Overrun by clovers	
3	N/A	N/A	3 : 9 present	N/A	3: 100+	overrun by clovers	
4	N/A	N/A	1 : 3	N/A	3: 20 ish	pretty grassy, not much weed activity	reapplied
5	N/A	3 : 10	1 : 3	N/A	3 : 100+		
6	1 : 3	3 : 13	2 : 5	N/A	3: 100+	clover takes up most area	
7	N/A	N/A	1 : 1	N/A	3: 60+		reapplied
8	2 : 4	N/A	1 : 2	N/A	N/A		
9	1 : 3	2 : 5	1 : 2	N/A	3 : 80+		reapplied
10	N/A	1 : 1	2 : 5	N/A	3 : 50+		reapplied
11	1 : 3	N/A	1 : 3	N/A	3 : 20 +		
12	N/A	N/A	2 : 5	2 : 4	3 : 10		reapplied
13	N/A	N/A	1 : 2	2 : 6	3 : 40+		
14	N/A	1 : 3	N/A	N/A	3 : 60+		
15	N/A	N/A	2 : 4	N/A	3 : 60+		reapplied
16	N/A	2 : 4	2 : 6	N/A	3 : 60+		reapplied
17	3 : 7	1 : 3	2 : 5	N/A	3 : 50		reapplied
18	1 : 1	2 : 5	2 : 4	N/A	3 : 100+	mainly filled with clover	
19	N/A	1 : 1	1 : 3	N/A	3 : 60		reapplied
20	1 : 3	1 : 3	2 : 5	N/A	3 : 60		reapplied
21	2 : 4	1 : 3	1 : 3	N/A	3 : 50 +		reapplied
22	1 : 2	1 : 1	1 : 1	N/A	3 : 15 ish		
23	3 : 7	N/A	N/A	N/A	3 : 20 ish		reapplied
24	3 : 12	N/A	1 : 3	N/A	3 : 30		
25	1 : 2	N/A	1 : 2	N/A	3 : 20		
26	N/A	N/A	2 : 4	N/A	3 : 10 +		reapplied
27	1 : 1	N/A	2 : 5	N/A	3 : 10 at least	clovers present appear to be small and hidden within the grass	
28	3 : 7	1 : 1	2 : 5	N/A	3 : 30+	many foxtails	reapplied
29	2 : 6	N/A	1 : 2	N/A	3 : 10+		reapplied
30	1 : 2	1 : 3	2 : 6	N/A	3 : 30+		

Figure 2: The weed inventory for the east side of each plot i.e. (score given) : (the number found)

ENVS492 -- Herbicide effectiveness ratings

Weed response to select herbicides **(0 = 0, 1= 1-3 2= 4 - 6 3 = 7+ , N/A)**

Plot #	Grass	Broadleaves		Perennials		Overall aesthetics	
	Foxtail	*Dandelion*	*Plantain*	*Creeping charlie*	*Clover*	*Comment box*	*Rating*
1	1 : 1 present	N/A	2 : 6 plantain present	N/A	3 : more than 30 present		
2	1 : 3 present	3 : 10 or more present	2: 5 plantain present	N/A	3 : more than 60		reapplied
3	1 : 1	1 : 2	1: 1 present	N/A	3 : more than 100+		reapplied
4	3 : 7 foxtail	N/A?	2 : 4	N/A	3: 25 ish		
5	1 : 1	N/A	1 : 3	N/A	3 : 75 +		reapplied
6	2 : 5	1 : 1	2 : 3	N/A	3 : 60+	clover mainly sprawling over corner	reapplied
7	N/A	1 : 1	2 : 4	N/A	3 : 100+	overrun with clover	
8	1 : 2	N/A	1 : 2	N/A	3 : 35+		reapplied
9	1 : 3	1 : 1	1 : 1	N/A	3 : 80+		
10	1 : 3	1 : 1	1 : 3	N/A	3 : 40+		
11	N/A	1 : 2	3 : 8	N/A	3 : 45+		reapplied
12	N/A	1 : 1	3 : 7	2 : 4	3 : 15+		
13	N/A	N/A	1 : 3	1 : 3	3 : 45+		reapplied
14	1 : 3	2 : 5	1 : 3	N/A	3 : 50+		reapplied
15	N/A	N/A	1 : 1	N/A	3 : 40+		
16	2 : 4	1 : 2	1 : 2	1 : 2	3 : 30+		
17	1 : 2	2 : 4	2 : 6	N/A	3 : 40 ish		
18	2 : 6	2 : 3	2 : 4	N/A	3 : 45+		reapplied
19	2 : 5	1 : 1	1 : 3	N/A	3 : 25+		
20	2 : 4	1 : 3	2 : 5	N/A	3 : 50+		
21	1 : 2	1 : 3	3 : 8	N/A	3 : 45+		
22	1 : 2	N/A	1 : 3	N/A	2 : 5		reapplied
23	2 : 5	N/A	1 : 2	N/A	N/A		
24	3 : 11	N/A	1 : 1	N/A	N/A		reapplied
25	3 : 8	N/A	1 : 2	N/A	3 : 15+		reapplied
26	1 : 1	1 : 2	2 : 5	N/A	3 : 10 at least	Clovers are hidden in between grass, not easily seen	
27	1 : 2	N/A	3 : 7	N/A	N/A	Dont see any clovers but I find that hard to believe	reapplied
28	1 : 2	N/A	1 : 3	N/A	3 : 30+		
29	2 : 5	N/A	2 : 6	N/A	3 : 10 ish		
30	2 : 6	N/A	1 : 3	N/A	3 : 40+		reapplied

Figure 3: The weed inventory for the west side of each plot i.e. (score given) : (the number found)

Analysis of Research and Project deliverables

Plot Ratings:

After collecting all of the plot ratings, we processed the data in a spreadsheet in order to compare one mixture to another. This was done by first averaging everyone's rating cards for each individual plot and weed. We then split the plots up based on which mixture was applied to them and found average ratings for each mixture. Finally, in order to account for how the ratings would have changed due to external factors (mostly weather as the experiment was conducted in the fall meaning the grass naturally changed color) we normalized the scores by subtracting the score of the control from all the other mixture's scores. This process was done on the ratings taken on 10/06 as well as on 10/21 and yielded the following graphs:

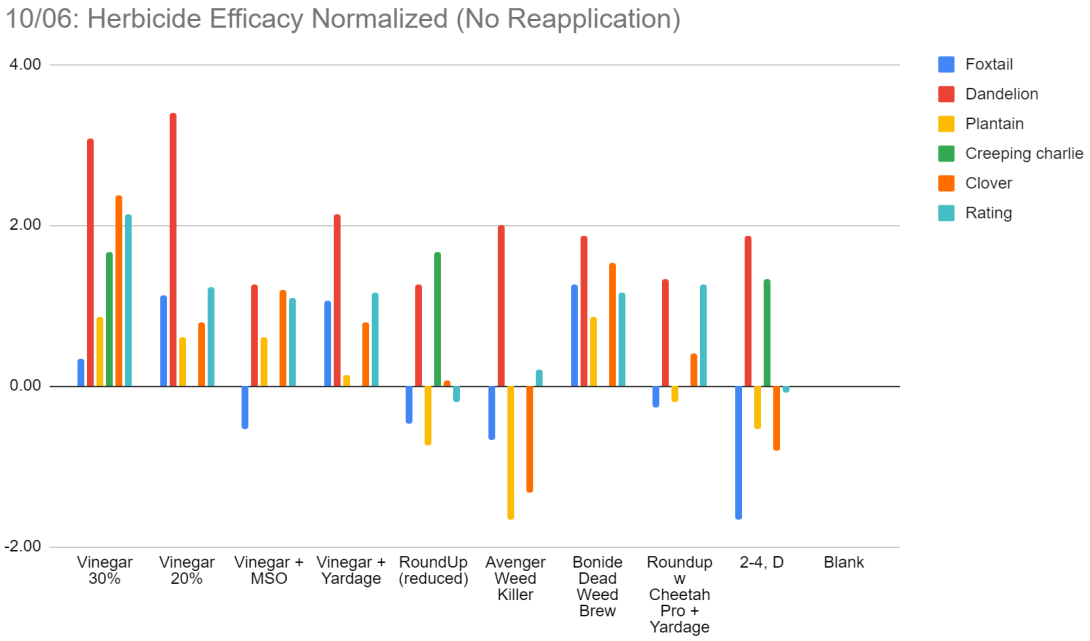

Figure 4: Average ratings of each herbicide by weed type for data collected on 10/06 of plots that did not have herbicide applied

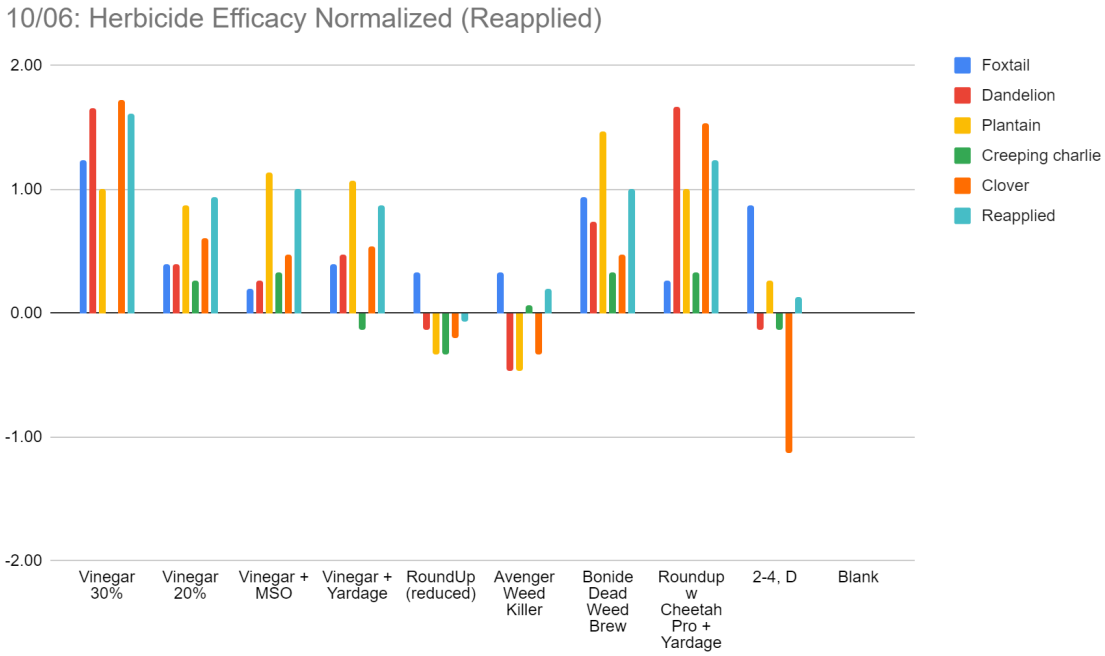

Figure 5: Average ratings of each herbicide by weed type for data collected on 10/06 for plots that had herbicide reapplied

These first two plots show the average rating of each herbicide mixture against each weed, with the first showing the ratings for the side of the plots that did not have herbicide reapplied and the next showing the side that was reapplied. This is a lot of data to see at once but it is noticeable that 30% vinegar proves very effective. It is interesting to see that vinegar meets or exceeds the effectiveness of the inorganic mix, especially compared to the non-reapplied side. This suggests that in cases where herbicide is used only once, vinegar could be a very promising option. The other vinegar mixtures were somewhat effective and overall showed that vinegar can be used as an alternative herbicide option whereas reduced Roundup and Avenger weed killer did not show promising results. It is important to note that some of the patterns seen in these graphs may be random as the individual weed ratings could be affected by randomness in plots.

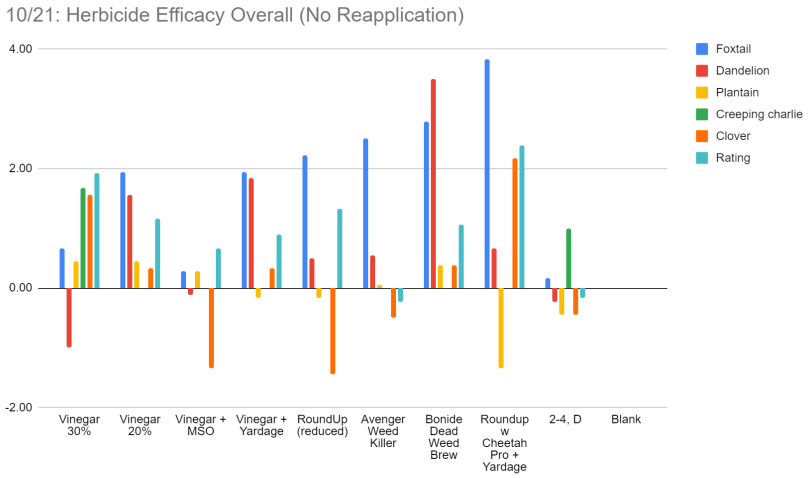

Figure 6: Average ratings of each herbicide by weed type for data collected on 10/21 for plots that did not have herbicide reapplied

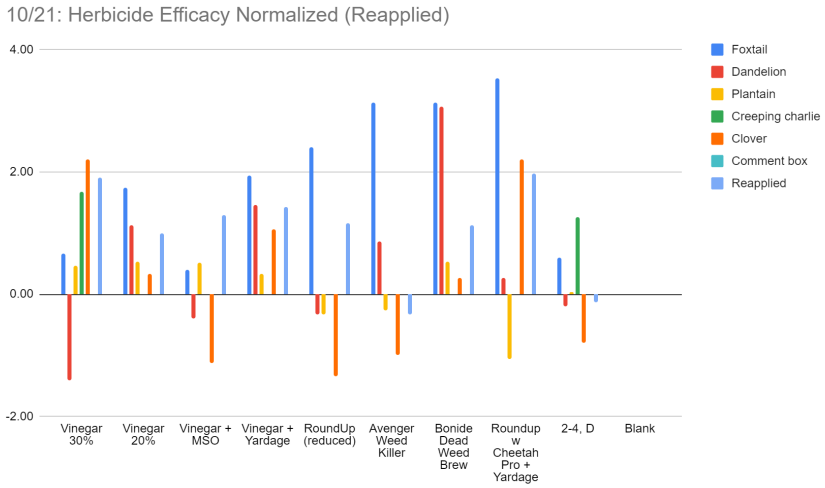

Figure 7: Average ratings of each herbicide by weed type for data collected on 10/21 for plots that had herbicide reapplied

These next plots seem to show that after more time the results of vinegar fade and are overcome by Roundup and Dead Weed Brew (surprisingly organic) for foxtail and dandelion. The vinegar treatment does seem to work well against creeping charlie and clover, something that cant be said for other mixtures.

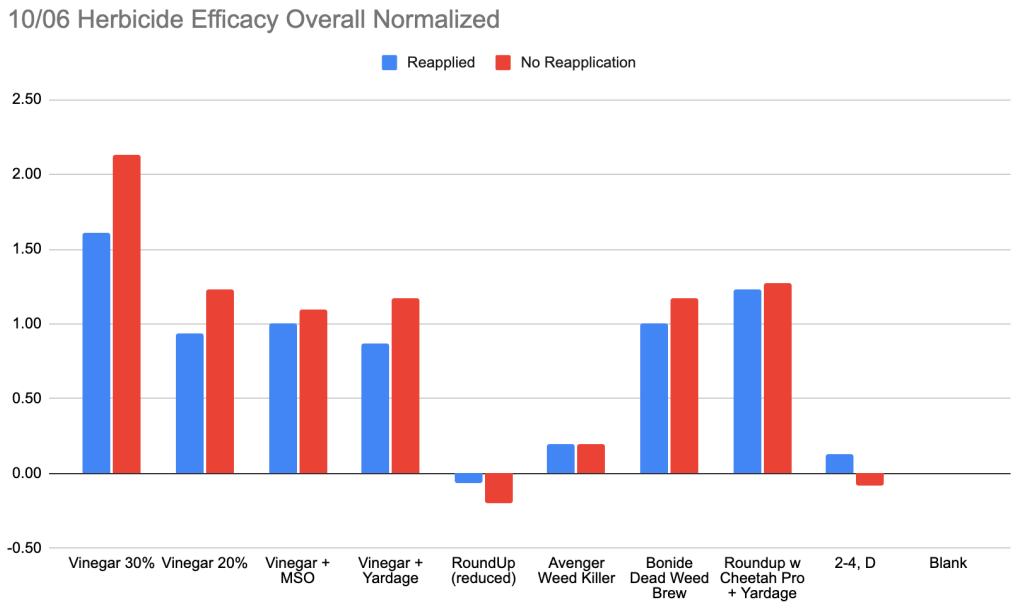

Figure 8: Average overall ratings of each herbicide effectiveness, showing the difference between reapplied and not reapplied for 10/06

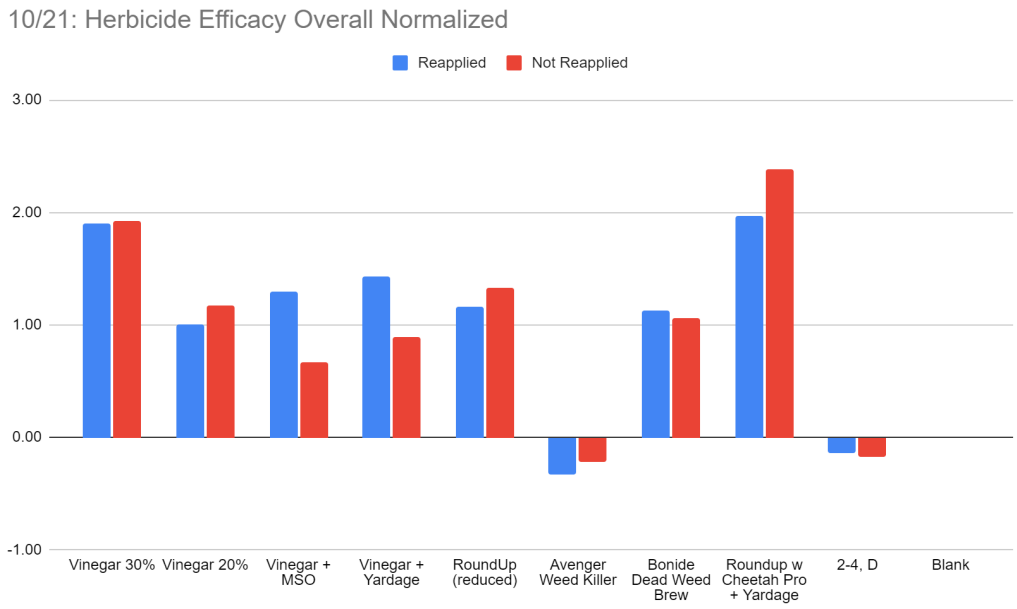

Figure 9: Average overall ratings of each herbicide effectiveness, showing the difference between reapplied and not reapplied for 10/06

Finally, these two graphs give us a much better sense of the overall effectiveness of these mixtures. 30% Vinegar was the most effective mixture in 10/06, implying that it has faster results at higher concentrations. In addition, the other mixtures had similar effectiveness as Roundup in 10/06 but after the additional two weeks, Roundup undeniably showed better results. 2-4D overall did not show to be any better than our control plots, which is surprising. Reduced Roundup did show results in 10/21 while Avenger weed killer actually had worse results than the control.

From looking at these graphs, it is clear that 30% vinegar and Roundup with Cheetah Pro and Yardage were most effective at managing weeds. The Roundup mixture's effectiveness does not come as a surprise since it is a commonly used mixture and contains harsh inorganic chemicals that most of the other mixtures do not. However, 30% vinegar's effectiveness was not predicted and as shown, it yielded the best results in the 10/06 rating. Although its later rating was surpassed by Roundup, it still presents a very viable alternative and our results even show that 30% vinegar yields results faster than other mixtures. After these two top mixtures, we see the other vinegar mixtures as well as Bonide Dead Weed. While not the best, these mixtures did prove to be effective and could perhaps be found useful for certain applications such as for controlling dandelions as the 10/06 results show for vinegar 20%. Finally, our results form a good argument against using 2-4 D and Avenger Weed Killer as they consistently proved ineffective.

Plot Percentages:

1 app				
Mixture	Date			
	09-28	10-06	10-13	10-23
Vinegar 30% (Green gobbler)	66.67%	**1.39%**	**0.83%**	**1.25%**
Vingegar 20%	67.92%	5.00%	**6.11%**	2.78%
Vinegar and MSO	**33.33%**	10.14%	11.11%	14.30%
Vinegar and Yardage	**64.72%**	**5.14%**	6.39%	20.28%
Roundup (reduced)	65.83%	71.81%	10.28%	7.22%
Avenger Weed Killer	66.67%	83.06%	99.31%	99.03%
Bonide Dead Weed Brew	66.67%	10.83%	10.56%	**2.36%**
Roundup with Cheetah Pro + Yardage	**31.53%**	**0.56%**	**0.00%**	**0.00%**
2-4, D	66.67%	81.81%	99.86%	98.75%
Blank plot	65.69%	90.56%	100.00%	98.47%

2 app				
Mixture	Date			
	09-28	10-06	10-13	10-23
A	66.67%	**0.83%**	**0.00%**	16.67%
B	67.92%	8.89%	**0.14%**	**0.14%**
C	**33.33%**	**6.25%**	**0.00%**	**0.00%**
D	**64.72%**	14.72%	0.83%	2.64%
E	65.83%	71.11%	13.06%	3.33%
F	66.67%	89.72%	95.28%	89.17%
G	66.67%	10.28%	0.69%	**0.14%**
H	**31.53%**	**0.28%**	0.28%	**0.00%**
I	66.67%	81.53%	99.86%	98.75%
J	65.69%	86.81%	97.78%	95.69%

Figure 9: The green space percentages calculations throughout the experiment, showing the difference between reapplied and not reapplied

Overall, we discovered that Vinegar 30%, Vinegar and MSO, Bonide Dead Weed Brew, and Roundup with Cheetah Pro and Yardage have the highest weed-killing efficiency, with the proportion of green spaces all decreased to nearly 0% after two applications.

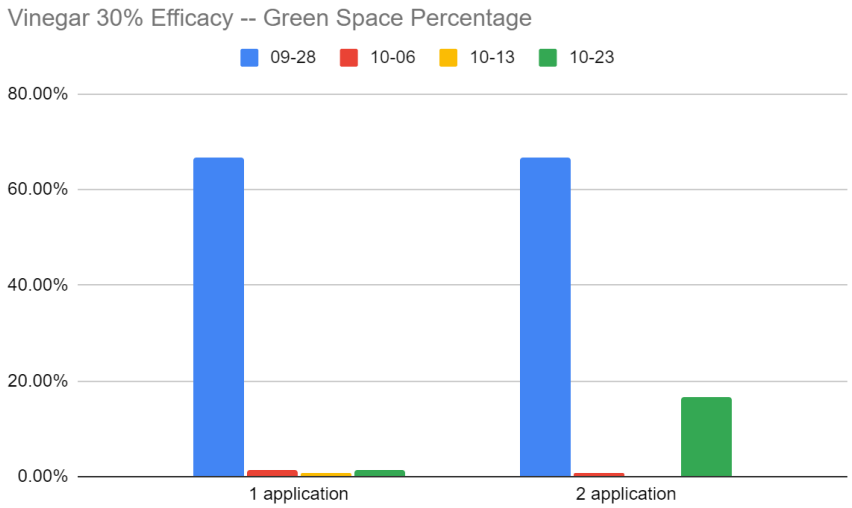

Figure 10: The green space percentages calculations specifically with Vinegar 30% mixture

Vinegar 30%: The green gobbler herbicide appeared to be quite efficient at the start of the experiment but afterward displayed a green space re-bounce. This phenomenon is most noticeable in the two applications dataset. On October 13, the percentage of green spaces was cut to 0%; however, on October 23rd, the percentage of green spaces grew by 16.67%, taking up about 1/5 of the plots.

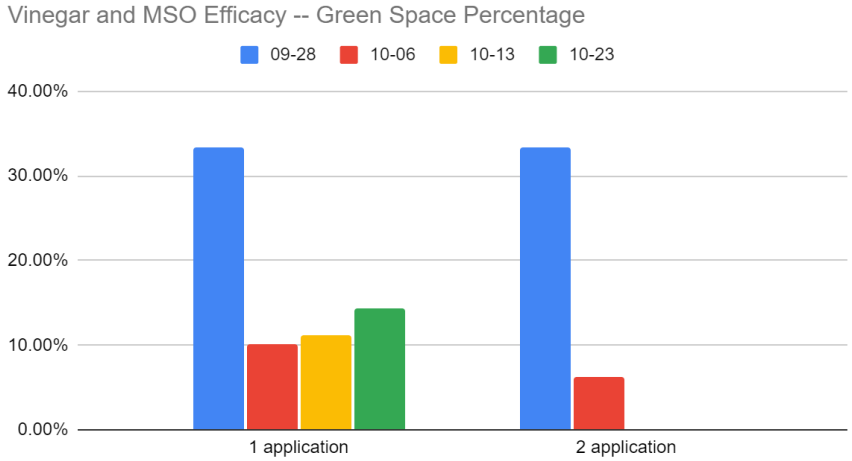

Figure 11: The green space percentages calculations specifically with Vinegar and MSO mixture

Vinegar and MSO: Aside from the control plots - Roundup with Cheetah Pro and Yardage - this herbicide mixture is most effective in a relatively short amount of time, killing approximately 70% of weeds a week after the first herbicide spray. However, when the results of one and two applications are compared, it is obvious that two applications of Vinegar and MSO destroyed more than 10% of the weeds at the end of the experiment.

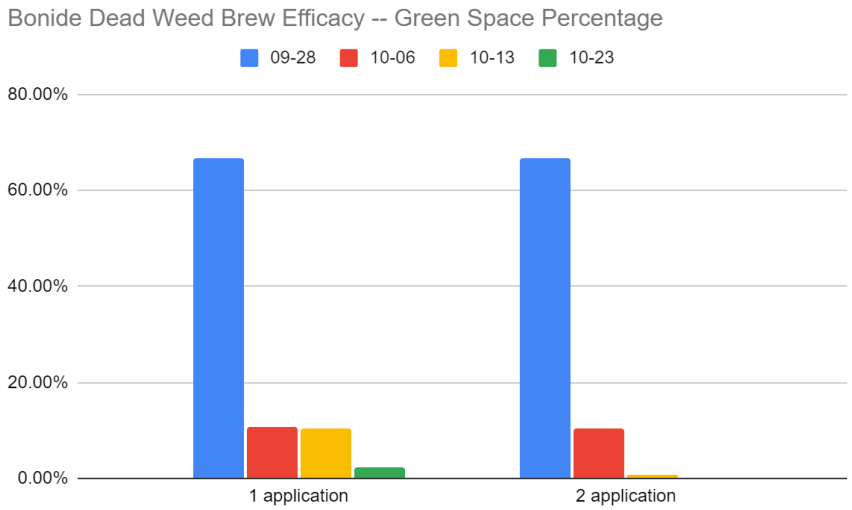

Figure 12: The green space percentages calculations specifically with Bonide Dead Weed Brew mixture

Bonide Dead Weed Brew: This herbicide mixture began to steadily kill the weeds; however, in relation to other mixtures, Bonide Dead Weed Brew had no advantages in terms of overall effectiveness or speed of weed removal prior to Oct.13th. Based on the figures from October 23rd, this mixture was placed 3rd among the remaining green places, suggesting its exceptional effectiveness.

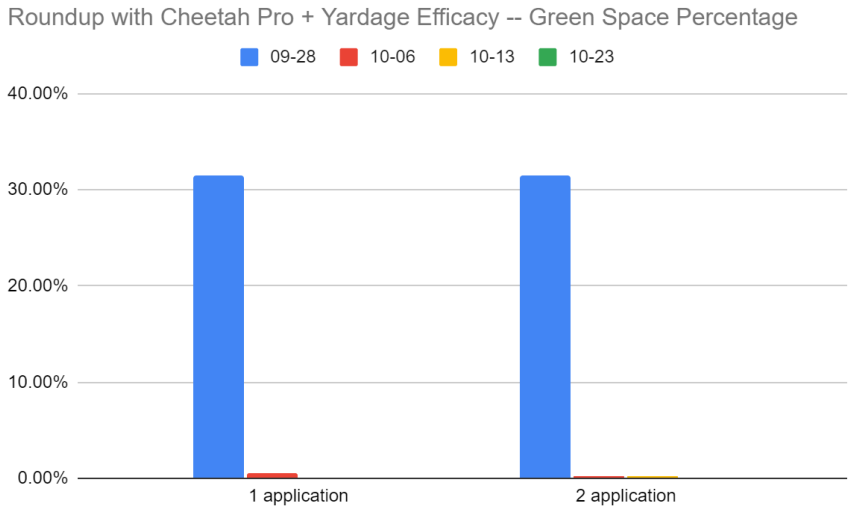

Figure 13: The green space percentages calculations specifically with Roundup with Cheetah Pro and Yardage mixture

Roundup with Cheetah Pro and Yardage: This herbicide mixture was utilized in our control plots. However, we can observe that with only one application, the percentage of green spaces dropped to 0.56% within two weeks and eventually killed all of the plants within the plot.

Research Implications

At the end of this experiment, upon analyzing our results we found that 30% Vinegar, the combination of Vinegar and MSO, Bonide Dead Weed Brew, and Roundup mixed with Cheetah Pro and Yardage are the best herbicides from the ones we tested. Specifically, the effectiveness of 30% Vinegar, as well as Roundup mixed with Cheetah Pro and Yardage, would be the most interesting to Paul. This is because, based on our results, we found that an organic herbicide (30% Vinegar) is just as effective as an inorganic herbicide (Roundup with Cheetah Pro and Yardage). In effect, Paul can choose to utilize the 30% vinegar herbicide without worrying about its effectiveness, thereby eliminating the release of hazardous chemicals contained in inorganic herbicides. Additionally, we also found that Roundup with Cheetah Pro and Yardage does not need to be reapplied every two weeks as not reapplying is equally effective. Currently, Paul's team applies herbicide once every two weeks and with our findings, he can minimize the number of times he reapplies herbicides. In effect, this will decrease the impact of air, water, and soil pollution from this inorganic herbicide while also saving him and his team time.

Recommendations and Innovations

Upon the beginning of this partnership, the end target was to apply our results to the real-world application of BrownWoods landscaping. As a team, we wanted to find organic herbicide alternatives that were on the same level of weed eradication efficacy as commonly used synthetic versions such as Glyphosate or Roundup. The next steps for our partner would be to integrate our recommendations into commercial use, moving towards our overall goal of eliminating the damage application and overapplication synthetic herbicides can have on the environment.

As a team, we all acknowledge our efforts to eliminate any possible errors, and yet still having some occur, the experiment as many others was not perfect. If we were to continue with this project, a first step would be to replicate our experiment and see if the same conclusions can be drawn again. But this time, include details we have learned along the way to make the process smoother and lower the probability of error. This includes instead of splitting each plot in half for a single and double application, simply giving each their own plots. A single mixture would have six plots in total, three of a single application, and three with two applications. We found the splitting of the plots to introduce the possibility of wrongly identifying which side was east or west. This led to extra time dedicated to deciphering the direction of each plot and confusion over which side had been applied more than once. Though we did our best to properly designate each side as either east or west, we are 95% confident in our identification, and therefore possible designation errors should be noted. This is why if this experiment were to be replicated, an indication of east and west on each plot should be included in any data gathering forms such as pictures.

When replicating this experiment, planting weeds into a plot, in addition to those naturally occurring would provide another angle for consideration. Actively planting the weeds would allow one to plant as many weeds as they want as well as different varieties. This will help the researcher pinpoint specific mixtures that work well for targeting specific weeds, as well as mixtures that work well overall. As well as assisting the researcher to keep track of the herbicide's effectiveness.

The team wishes for this experiment to make a difference here in the Champaign-Urbana area and help be one step closer to saving the world.

Appendix

Data

1. *Extension - department of agronomy: Iowa State University*. Department of Agronomy. (2022, May 2). Retrieved December 2, 2022, from https://www.agron.iastate.edu/extension/
2. *Corn Herbicide Effectiveness Ratings*. 2005, http://extension.agron.iastate.edu/weeds/reference/wc92/WC92-2005/HerbEffRating.pdf.

Budget

Herbicide Mixture Cost Comparison	
Mixture	**$ per gallon**
Vinegar 30% (Green gobbler)	$26.98
Vinegar 20%	**$22.37**
Vinegar and MSO	$36.20
Vinegar and Yardage	$24.60
Roundup (reduced)	**$14.50**
Avenger Weed Killer	$79.99
Bonide Dead Weed Brew	**$19.87**
Roundup with Cheetah Pro + Yardage	$26.80
2-4, D	$73.40
SUM	$324.71