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Soil Compaction Final Report

BACKGROUND REPORT

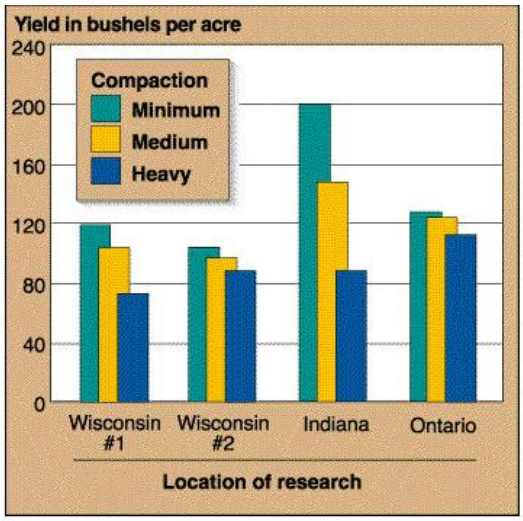
Soil compaction is becoming a major problem, especially for agriculture, in this country. Soil compaction, or the reduction of space between the different pores in the soil, causes a new structure of soil to form and as a result, reduces the growth rate in plants, including roots. The new soil structure can be created in a variety of different ways including: the cutting down of forests, the building of roads, and farming (University of Minnesota, 2010). In urban areas, roads are the major cause of soil compaction, and as the traffic presses over them and compacts the soil, the roots of trees and other large plants with similar extensive rooting systems have a more difficult time growing, staying healthy, and surviving.

One of the main reasons for plant malnourishment is because of what compaction does to the flow of water. Water flow through soil channels is critical because water is one of the most essential components of photosynthesis, the transformation of sunlight into energy. Compacted soil, because it contains fewer natural channels for water due to its smaller pores, causes increase in soil density which then causes the soil to become more resistant to water infiltration; and less water is able to be absorbed by the soil (Cranfield University, 2009). However, less water means that the rate of photosynthesis in the plants living there declines because of the limited supply. Since photosynthesis is necessary in order for plants to create the food which they need to run

their cells and to grow, a plant where less photosynthesis is occurring will therefore be less healthy (Frisby & Pfost, 1993).

Along with impacting the overall health of plant life, photosynthesis also helps plants to grow. Without photosynthesis, dangerous situations in agriculture develop. If there is a lack in photosynthesis, the growth of the tree is not only impacted, but so are its roots. The roots of plants have difficulties penetrating the soil and reaching down to where the nutrients and water are located if compaction is present. As Graph 1 (Frisby & Pfost, 1993) shows, the heavier the compaction, the less corn farmers are able to collect. One source gets so specific as to say that compaction decreases the amount of crops by 3-13 bushels, depending on the amount of compaction present. (Roegge, Mike, 2010) We can compare the corn and the trees because they are both plants which need nutrients found in soil to survive. All of these nutrients are transferred to the plant by the tree roots, which cannot thrive in areas of high compaction. If photosynthesis in the plant is unable to take place, this means that the symbiotic relationship between the tree roots and fungi is altered because the fungi are unable to transport the necessary nutrients, minerals, and water to the tree roots.

Graph 1



Tree roots are not only important for plant growth but also for decomposers. Fungi, which are recyclers who live in damp and rainy conditions, and tree roots are essential to each other because of their symbiotic relationship. Fungi are critical for plants' survival in the environment and they work together in order to strengthen each other (Nardi, 2003). Professor A. B. Frank (Nardi, 2003) has proven that parts of fungi bring water and nutrients to the soil's surface for the plants roots, which are then used by the plant to survive. Along with nutrients and water, fungi also give necessary minerals to the roots which they receive by extracting minerals from the soil, carrying it back to the surface. In return, the plants' roots transport the essential biological molecules and energy obtained in photosynthesis to the fungi. Very few of the elements needed by plants are received through the air and water, but instead from the soil through the fungi, who retrieve the elements needed by the tree and bring them to the roots. Trees with low numbers of fungi in their soil are more likely to be unhealthier (Nardi, 2003).

This symbiotic relationship does not function properly when fungus' basic needs are limited. When soil pressure changes, the rate of infiltration, or filtering, usually changes as well. Slowed rates of infiltration can cause the soil to take longer to obtain moisture. In compacted soil, the percentage rate of water and air to soil is much less than that of non-compacted soil. These elements directly cause the amount of fungi and other decomposers to decrease because of the decomposers' need for water, oxygen, and moisture to survive (Nolte & Fausey, 2010). Because of the lack of nutrients in the soil, the fungi can't give the plants the nutrients they need. Also, because of the compaction, the plants, in return, can't give as much energy from photosynthesis to the fungi. This proves that because of compaction, both parties suffer.

Not only is moisture limited but so are nutrients. During soil compaction, the absorption of nutrients is more difficult for plants because the density of the soil limits the space for root

growth to find the nutrients deep below the soil. Soil compaction also alters temperature and soil moisture, which controls the roots' absorption and release of nutrients out of the soil. (United States Department of Agriculture, 2001). The nutrients created during decomposition include sulphur, nitrogen, potassium, magnesium, calcium, and phosphorus (Scandelleri, Francesca, 2009). The more compaction in an area, the less decomposition can take place, and the food chain is disrupted.

Nutrients are essential to fungi because, as mentioned above; the symbiotic relationship involves the transport of nutrients between roots and fungi. Because fungi play such an important role in the growth of plants, we have decided to use fungi as our testing tool; to see if compaction caused by the road beds in the RPCS backwoods is affecting the growth of the roots of trees. At Roland Park Country School, many roads have been built amongst plants and trees in the backwoods which have been compacting the soil. Every time a vehicle is driven on the road, the soil compacts more and more. We believe that the creation of roads in our backwoods and everywhere on the Roland Park campus has been detrimental to the fungi levels and therefore harmful to the healthiness of our plant life. Along with at school, roads also cause a huge amount of compaction in our world today. Because we know that fungi directly relates to compaction and tree health we have chosen to test for it. To test for fungi and compaction, we have decided to extract our soil samples from trees around a road on the RPCS campus, however, our negative control is not near this road at all. The trees we used are all in the same general area to make sure our controlled variables are all the same, excluding our negative control. Based on existing research, we hypothesize that the roots of trees closer to the road will have lower levels of fungi because of the increased amount of compaction on their roots. Therefore, the roots of trees

farther away from the road bed will have higher levels of fungi and will overall, be much healthier.

PROCEDURE OF EXPERIMENT

I. Problem: Is the health of tree roots on the RPCS campus being negatively impacted by compaction from our road beds?

II. Hypothesis: The trees with most of their roots located under the school's road have lower densities of soil fungi.

III. Procedure:

a. Independent Variable: distance of trees from road bed
b. Dependent Variable: density of soil fungi located at the base of the tree
c. Negative Control: soil samples from a tree located where there is little to no compaction
d. Controlled Variables:

- The distance of soil taken from tree trunk
- Amount of soil taken as a sample
- Environmental factors- by taking at the same time of year and day
- Amount of water
- Size of pipette
- Size of petri dishes
- Size of culture tube
- Type of water
- Degree of dilutions
- Type of agar
- Number of days that fungi are left on grow plates
- Which dilutions plated
- Size of soil extractor
- Tool used to measure soil (soil extractor)
- Amount of soil put into test tubes
- Amount of sterile water put into test tubes
- Amount of soil-water extracted from test tubes placed onto fungus agar

e. Step by Step Instructions

1. For steps 2-8 make sure to label each of the plastic bags for your samples with its appropriate identification(X-Y-Z), where X means the tree number, Y means the trial, and Z the sample #.
2. Go to the Maple tree located at N 39.35695° and W 76.63631° that is 3.6 meters in a perpendicular line away from the edge of the road. Once you have found it, mark the area of soil 50 centimeters from the base of the tree with flags, labeling the flags by the tree number (tree #1), and record coordinates.
3. In that same area that you found tree 1, find the maple tree at N 39.35700° and W 76.63631° that is 19 meters in a perpendicular line away from the edge of the road. Once you have found the second tree, mark the area of soil 50 centimeters from the base of the tree with flags, labeling the flags by the tree number (tree #2), and record coordinates.
4. In the same general area as the previous trees, find the Maple tree at N 39.35694° and W 76.63591° that is 6.2 meters in a perpendicular line away from the edge of the road. Once you have found the third tree, mark the area of soil 50 centimeters from the base of the tree with flags, labeling the flags by the tree number (tree #3), and find coordinates.
5. In the same area as the previous trees, find the Maple tree at N 39.35681° and W 76.63585° that is 1.1 meters in a perpendicular line away from the edge of the road. Once you have found the fourth tree, mark the area of soil 50 centimeters from the base of the tree with flags, labeling the flags by the tree number (tree #4) and record coordinates.
6. Find the negative control Maple tree at N 39.35807° and W 76.63914°. Mark the area of soil 50 centimeters from the base of the tree with flags, labeling the flags by the tree number (tree #5), and record coordinates.
7. NOTE: The soil samples for step 8 all have to be taken on the same day and time so that the environmental variables are all controlled for the different samples.
8. In the marked area of soil 50 cm away surrounding the base of each tree, use a soil extractor tool with a width of 2 cm and drill it into the soil until the first mark is in line, 15 cm of soil, with the ground. Pull up the soil extractor and retrieve the soil inside, placing it into its appropriately labeled corresponding plastic bag. Repeat this step two more times for a total of three samples from each tree, so 15 samples per trial.
9. Start setting up your experimental process by labeling groups of three test tubes for each tree sample exactly like plastic bags (X-Y-Z.). Out of these three test tubes, one tube should be labelled 10^{0}, one should be labelled 10^{-1}, and one should be labelled 10^{-2}. This means that for one trial, you should have 45 labelled test tubes (3 tubes x 3 samples x 5 trees).The testing for each trial must happen at the same time on the same day, otherwise, you will get inaccurate results. To test for fungi follow the following steps: (the following is for <u>one</u> soil sample)
    a. You should have already labelled a group of 3 test tubes (X-Y-Z) depending on the trial #, tree #, and sample #.
    b. Use a clean, new transfer pipette to add 10 ml to the 15 ml culture tube labelled "10^{-0}".

c. Use the same pipette to add 9 ml to a second 15 ml culture tube labelled "10^{-1}."
d. Repeat step c one more time to the additional 15 ml culture tube labelled "10^{-2}" respectively.
e. Place 1 cc of the soil sample into the "10^{-0}"culture tube. Start with the first soil sample from the first tree in the first trial. After testing each sample from the first tree in the same trial, move on to the second tree, and repeat this until you test all samples from all the trees of one trial. Repeat these steps for the other trials as well.
f. Cap the tube and shake vigorously.
g. Using a new clean pipette, remove 1 ml of the soil/water mixture from the "10^{-0}" tube and place into the "10^{-1}" tube.
h. Cap and shake vigorously.
i. Using the same pipette in step g., remove 1 ml of the soil/water mixture from the "10^{-1}" tube and place into the "10^{-2}" tube.
j. Cap and shake vigorously.
k. You should now have a total of three culture tubes.
l. Plate 100 µl samples from each of the three tubes (dilutions 10^{-0}, 10^{-1} & 10^{-2}) onto their own separate, appropriately labelled Petri plates containing nutrient agar. Label these Petri plates in the (X-Y-Z) format previously mentioned in step 1, on the previous page.
m. Allow to grow for 5 days.
n. Examine and record the numbers on each of the set of plates for each of the soil samples for individual fungal colonies and choose the plate with the fewest colonies (but at least 5) to make your estimates of the number of bacteria in the original 1 cc soil sample using the following formula:

Microbes in 1 cc of soil = # Colonies on sheet x 10^2x 10 |
dilution # at which these colonies were found I

10. Using the same five trees which have already been found, repeat steps 8 through 9 two more times for trial #2 and trial #3.

DATA AND ANALYSIS

Data Tables

Trial #1 Data`

Number of Fungi for Trial 1 Sample 1	Types of Fungi in 1cc of Soil		Number of Total Fungi in 1cc of Soil
Tree # (meters from road)	Number of yeast in 1 cc of soil	Number of molds in 1 cc of soil	
Tree 1 (3.6 meters)	50000 yeasts	90000 molds	140000 fungi
Tree 2 (19 meters)	1000 yeasts	2000 molds	3000 fungi
Tree 3 (6.2 meters)	2000 yeasts	100 molds	2100 fungi
Tree 4 (1.1 meters)	9000 yeasts	4000 molds	13,000 fungi
Tree 5 (negative control)	10000 yeasts	10000 molds	20000 fungi

Number of Fungi for Trial 1 Sample 2	Types of Fungi in 1cc of Soil		Number of Total Fungi in 1cc of Soil
Tree # (meters from road)	Number of yeast in 1 cc of soil	Number of molds in 1 cc of soil	
Tree 1 (3.6 meters)	3,000 yeasts	1,000 molds	4,000 fungi
Tree 2 (19 meters)	2,000 yeasts	2,000 molds	4,000 fungi
Tree 3 (6.2 meters)	70,000 yeasts	20,000 molds	90,000 fungi
Tree 4 (1.1 meters)	10,000 yeasts	2,000 molds	12,000 fungi
Tree 5 (negative control)	1,900 yeasts	500 molds	2,400 fungi

Number of Fungi for Trial 1 Sample 3	Types of Fungi in 1cc of Soil		Number of Total Fungi in 1cc of Soil
Tree # (meters from road)	Number of yeast in 1 cc of soil	Number of molds in 1 cc of soil	
Tree 1 (3.6 meters)	10,000 yeasts	10,000 molds	20,000 fungi
Tree 2 (19 meters)	2,000 yeasts	400 molds	2,400 fungi
Tree 3 (6.2 meters)	120,000 yeasts	1,000 molds	121,000 fungi
Tree 4 (1.1 meters)	10,000 yeasts	4,000 molds	14,000 fungi
Tree 5 (negative control)	10000 yeasts	10000 molds	20000 fungi

Trial #2 Data

Number of Fungi for Trial 2 Sample 1	**Types of Fungi in 1cc of Soil**		**Number of Total Fungi in 1cc of Soil**
Tree # (meters from road)	Number of yeast in 1 cc of soil	Number of molds in 1 cc of soil	
Tree 1 (3.6 meters)	10,000 yeasts	3,000 molds	13,000 fungi
Tree 2 (19 meters)	30,000 yeasts	20,000 molds	50,000 fungi
Tree 3 (6.2 meters)	*Data was lost*	*Data was lost*	*Data was lost*
Tree 4 (1.1 meters)	10,000 yeasts	10,000 molds	20,000 fungi
Tree 5 (negative control)	10,000 yeasts	20,000 molds	30,000 fungi

Number of Fungi for Trial 2 Sample 2	**Types of Fungi in 1cc of Soil**		**Number of Total Fungi in 1cc of Soil**
Tree # (meters from road)	Number of yeast in 1 cc of soil	Number of molds in 1 cc of soil	
Tree 1 (3.6 meters)	1,000 yeasts	10,000 molds	11,000 fungi
Tree 2 (19 meters)	10,000 yeasts	4,000 molds	14,000 fungi
Tree 3 (6.2 meters)	40,000 yeasts	10,000 molds	50,000 fungi
Tree 4 (1.1 meters)	30,000 yeasts	10,000 molds	40,000 fungi
Tree 5 (negative control)	30,000 yeasts	20,000 molds	50,000 fungi

Number of Fungi for Trial 2 Sample 3	**Types of Fungi in 1cc of Soil**		**Number of Total Fungi in 1cc of Soil**
Tree # (meters from road)	Number of yeast in 1 cc of soil	Number of molds in 1 cc of soil	
Tree 1 (3.6 meters)	10,000 yeasts	5,000 molds	15,000 fungi
Tree 2 (19 meters)	30,000 yeasts	30,000 molds	60,000 fungi
Tree 3 (6.2 meters)	120,000 yeasts	60,000 molds	180,000 fungi
Tree 4 (1.1 meters)	5,000 yeasts	4,000 molds	9,000 fungi
Tree 5 (negative control)	20,000 yeasts	30,000 molds	50,000 fungi

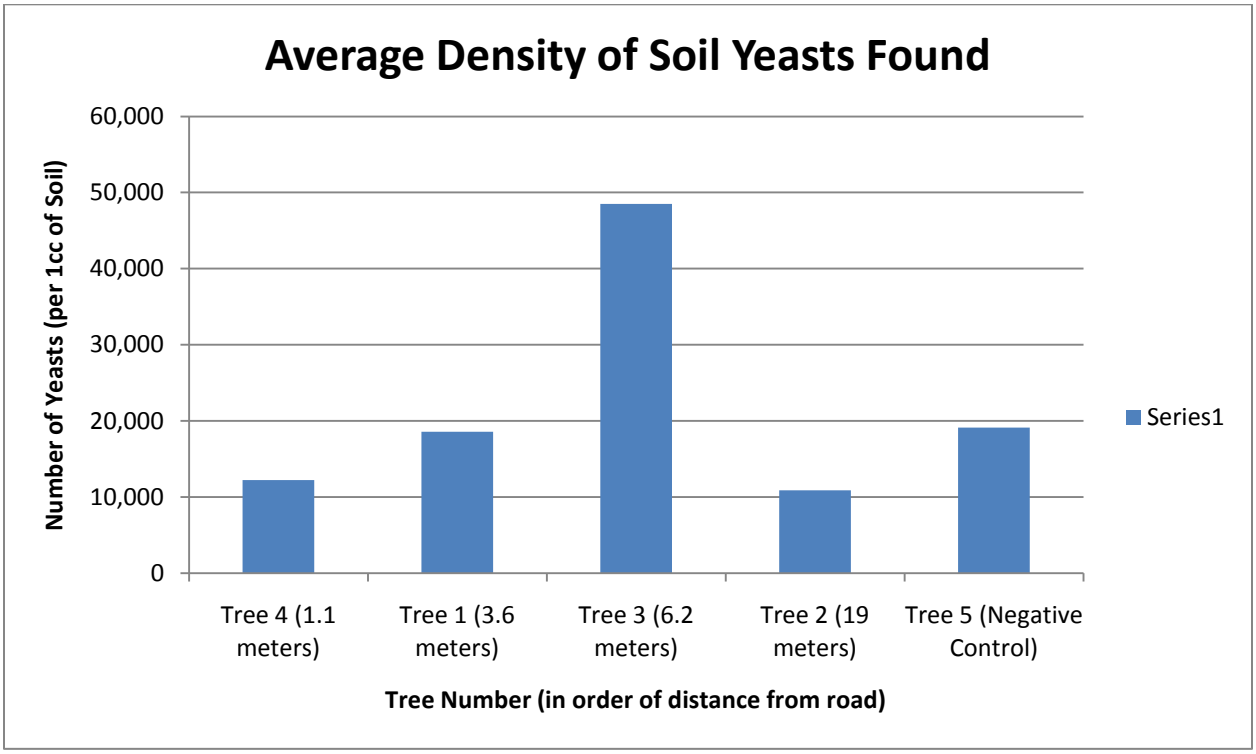
Trial #3 Data

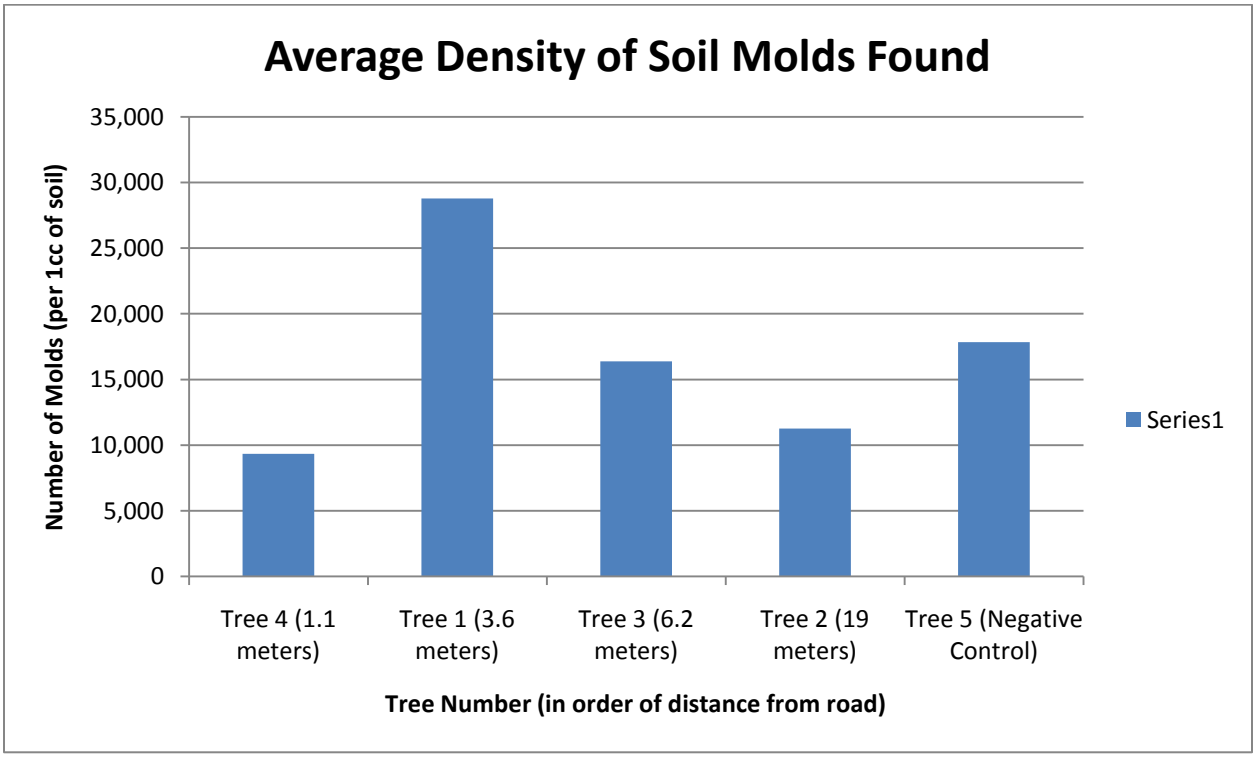
Number of Fungi for Trial 3 Sample 1	Types of Fungi in 1cc of Soil		Number of total fungi in 1cc of Soil
Tree # (meters from road)	Number of yeasts in 1cc of Soil	Number of molds in 1cc of Soil	
Tree 1 (3.6 meters)	10,000 yeasts	30,000 molds	40,000 fungi
Tree 2 (19 meters)	10,000 yeasts	20,000 molds	30,000 fungi
Tree 3 (6.2 meters)	10,000 yeasts	20,000 molds	30,000 fungi
Tree 4 (1.1 meters)	6,000 yeasts	20,000 molds	26,000 fungi
Tree 5 (negative control)	30,000 yeasts	20,000 molds	50,000 fungi

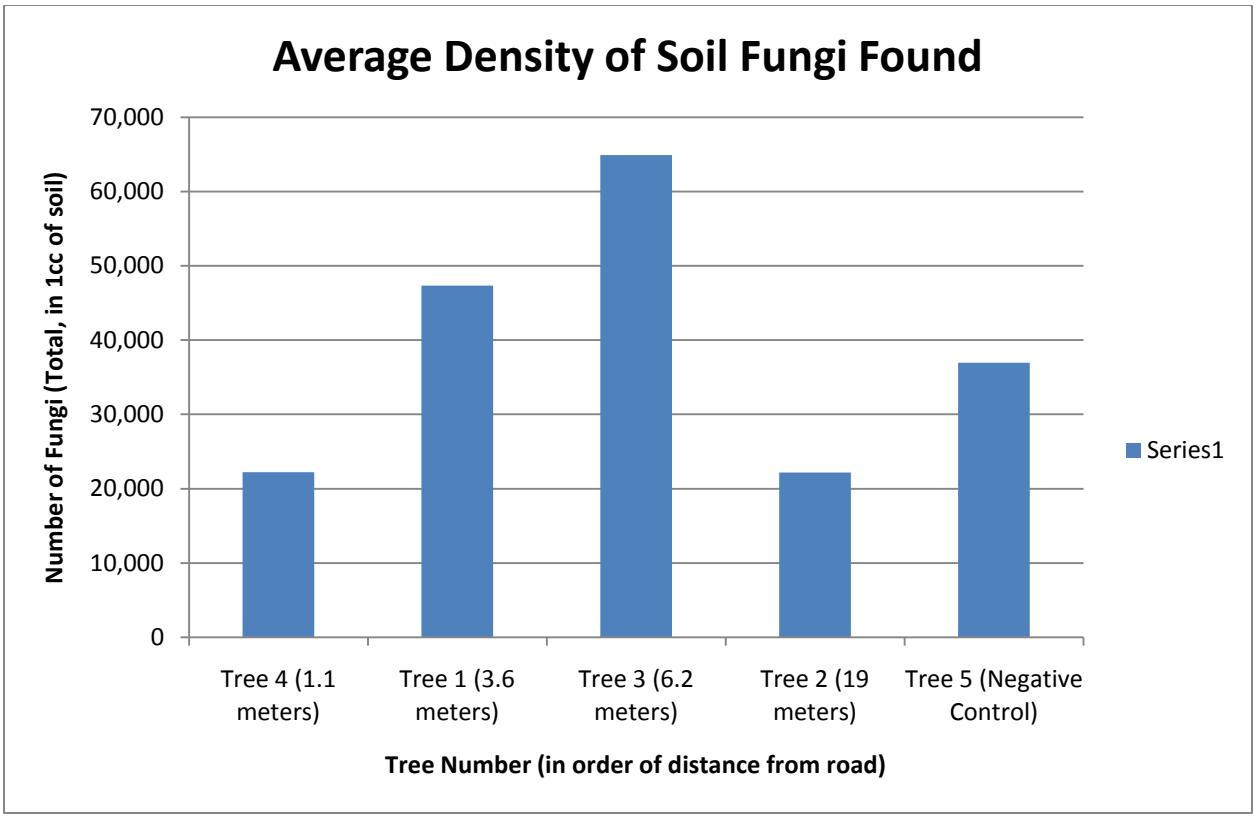
Number of Fungi for Trial 3 Sample 2	Types of Fungi in 1cc of Soil		Number of total fungi in 1cc of Soil
Tree # (meters from road)	Number of yeasts in 1cc of Soil	Number of molds	
Tree 1 (3.6 meters)	60,000 yeasts	100,000 molds	160,000 fungi
Tree 2 (19 meters)	10,000 yeasts	20,000 molds	30,000 fungi
Tree 3 (6.2 meters)	6,000 yeasts	10,000 molds	16,000 fungi
Tree 4 (1.1 meters)	20,000 yeasts	10,000 molds	30,000 fungi
Tree 5 (negative control)	30,000 yeasts	20,000 molds	50,000 fungi

Number of Fungi in Trial 3 Sample 3	Types of Fungi in 1cc of Soil		Number of total fungi in 1cc of Soil
Tree # (meters from road)	Number of yeasts in 1cc of Soil	Number of molds in 1cc of Soil	
Tree 1 (3.6 meters)	13,000 yeasts	10,000 molds	23,000 fungi
Tree 2 (19 meters)	3,000 yeasts	3,000 molds	6,000 fungi
Tree 3 (6.2 meters)	20,000 yeasts	10,000 molds	30,000 fungi
Tree 4 (1.1 meters)	10,000 yeasts	20,000 molds	30,000 fungi
Tree 5 (negative control)	30,000 yeasts	30,000 molds	60,000 fungi

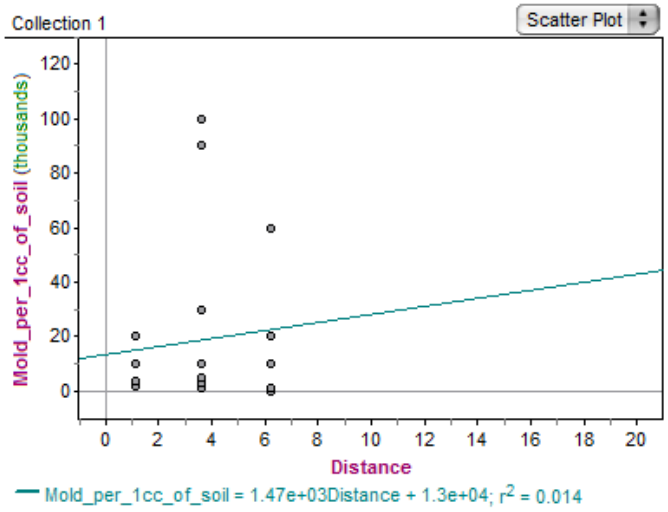
Graphs


Average Density of Soil Yeasts Found
Number of Yeasts (per 1cc of Soil)
60,000
50,000
40,000
30,000
20,000
10,000
0
Tree 4 (1.1 meters)
Tree 1 (3.6 meters)
Tree 3 (6.2 meters)
Tree 2 (19 meters)
Tree 5 (Negative Control)
Tree Number (in order of distance from road)
Series1

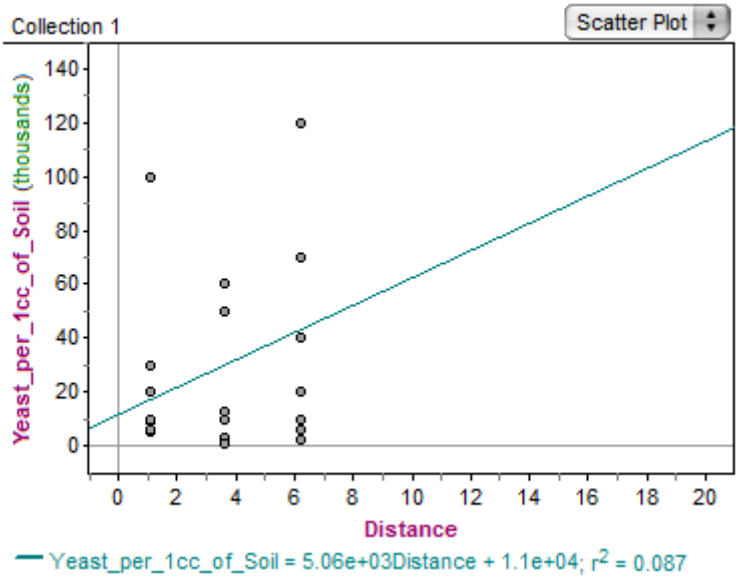

Average Density of Soil Molds Found
Number of Molds (per 1cc of soil)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Tree 4 (1.1 meters)
Tree 1 (3.6 meters)
Tree 3 (6.2 meters)
Tree 2 (19 meters)
Tree 5 (Negative Control)
Tree Number (in order of distance from road)
Series1



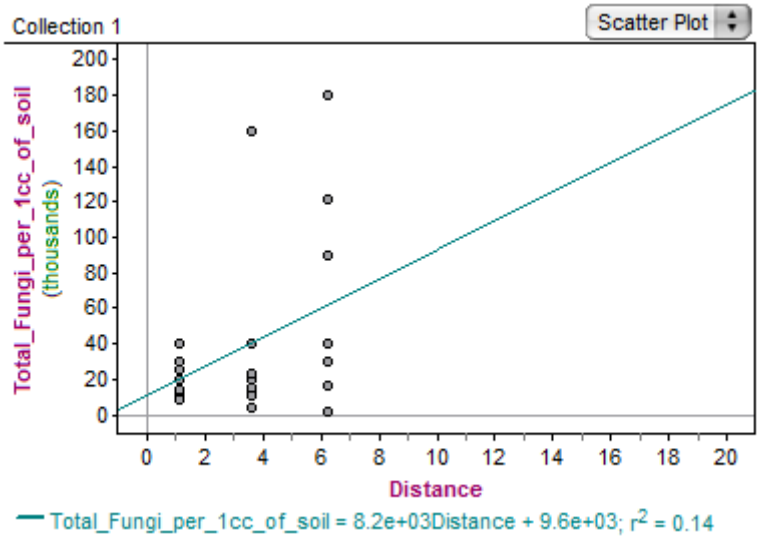
Distance of Tree from Road Bed vs. Mold Density



Distance of Tree from Road Bed vs. Yeast Density



Distance of Tree from Road Bed vs. Total Fungi Density



P Values Table

YEAST	1 (3.6 meters)	2 (19 meters)	3 (6.2 meters)	4 (1.1 meters)	5 (NC)
1	----------		.145		.947 (5.3%)
2		----------			.145 (85.5%)
3		.070	----------		.140 (86%)
4	.419			----------	.156 (84.4%)
5					----------

MOLD	1 (3.6 meters)	2 (19 meters)	3 (6.2 meters)	4 (1.1 meters)	5 (NC)
1	----------		.410		.430 (57%)
2		----------			.199 (80.1%)
3		.520	----------		.850 (15%)
4	.172			----------	.047 (95.3%)
5					----------

TOTAL	1 (3.6 meters)	2 (19 meters)	3 (6.2 meters)	4 (1.1 meters)	5 (NC)
1	----------		.557		.628 (37.2%)
2		----------			.147 (85.3%)
3		.095	----------		.248 (75.2%)
4	.244			----------	.067 (93.3%)
5					----------

CONCLUSION

Our hypothesis which states that compaction negatively impacts the fungi levels of the trees on the RPCS campus was proven correct. This data was proven in many aspects of our experiment. First of all, lots of repetition in our testing allowed us to be confident in our results. In total we had 45 soil samples, assuring that if we were to lose some of our data, or if we made a mistake in one aspect of a test, we would still have enough correct information to average and give us the correct results. We also had two negative control Maple trees which served as comparisons to our other trees close to the road. This brings us to our first piece of evidence, the P values shown above. As you can see from our data table of P values, each tree that was compared to our farthest negative control tree had a high percentage, with some as high as 95.3%. These rates proved that no matter what conclusion we came to, we were guaranteed that our results were definite.

Another aspect of our testing which proves our hypothesis correct is our bar graphs. Looking at the average density of soil fungi on page 12, tree 4, which is 1.1 meters from the road, tree 1, which is 3.6 meters from the road, and tree 3, which is 6.2 meters from the road, all have significant increases in total fungi levels from one tree to the next. Almost all of our data proves us correct, except for tree 2. Tree 2 is 19.2 meters away from the road, and is therefore

too far for the roots of the tree to reach the road. Because it is so far away that the road does not affect its roots, tree 2 can also be considered our negative control. It is shown from our yeast and mold bar graphs that tree 4's yeast and mold levels are about equal, which is accurate for our expectations. In tree 1, mold levels are higher, which is also accurate for what we expected. However, the levels of yeasts in tree 3 are increased, which is abnormal. A yeast increase tells us that the tree needs more protective decomposers to fight something off. Therefore our group concluded that there must be another factor affecting the health of this tree. Also, if tree 1 is compared to tree 3, which are the closest in distance from the road, the P value is .557. This proves that we cannot be sure that compaction is the only variable affecting tree 3's fungi levels.

Fathom also helps prove our hypothesis correct. When plugging in our data for tree 2 into Fathom, our graphs were thrown out of sync and our data was jumbled. However, when we took tree 2 out of the graph, treating it as a negative control, we saw from the graphs on pages 12-13 that the amounts of fungi had a significant increase, gradually increasing for each tree farther from the road, with correlations higher than 10%.

From all of our testing and data, our group has concluded that compaction from the RPCS road affects the fungi levels around the tree's roots. We can now perform some deeper research on how to help reduce compaction created by the road. Something we could test for would be the lightest type of cement for roads. If lighter cement was used for the road, it wouldn't put as much weight on the soil, and would reduce compaction levels. Also, the equipment used to build the roads may also cause compaction on the sides of the road. We may research a way to build a road using light machinery without taking efficiency from the task. Lastly, we could test for other variables which would affect fungi levels, for instance like the variables affecting the health of tree 3. Overall; however, through a long series of tests and analyzing, our group has concluded that the road in the RPCS backwoods is compacting the soil and therefore affecting the health of the tree roots, specifically the fungi levels.

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