PESTICIDES IMPAIR THE GROWTH OF SUNFLOWER AND PUMPKIN SEEDS

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ABSTRACT

*Human activities increase the amount of chemicals in Earth's various biogeochemical cycles and ultimately lead to large scale ecosystem impacts. Pollution can have particularly detrimental effects on plants, which are essential primary producers that support all aerobic organisms and their respective ecosystems. To study this, we planted two fast growing seeds: sunflower (*Helianthus annuus*) and pumpkin (*Cucurbita pepo*), and observed the effects of pesticides, and urban runoff on the germination and growth of seeds. Our results show that the sunflowers showed the most growth with the urban runoff and deionized water, and the pumpkins showed the most growth with the dilute Ortho, an insecticide, and deionized water. Both groups were negatively impacted with the Roundup solution. Overall, the data reveals negative impacts that pollution has on ecosystems and can be used to support regulation of pesticides.*

Keywords: Pesticides, Plant growth, Pollution, Pumpkin, Sunflower

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INTRODUCTION

Human activities disturb ecosystems and discharge pollution into the Earth's air, water, and soil. The integration of numerous chemicals and nutrients into the various biogeochemical cycles that promote life and the overall functioning of ecosystems has adverse effects as well as many unknown consequences. Every day humans send out extensive substances into the environment through agriculture, transportation, energy production, and industry. Urban runoff alone doses nearby ecosystems with elements such as lead, calcium, iron, copper, sodium, and zinc (Aljazzar and Kocher 2016). Pollution comes in many forms and finds its way into freshwater and marine bodies, as well as the atmosphere and soil.

Plants, as autotrophs and the bases of many ecosystems, must receive special attention regarding how they are affected by the pollution and ultimately what can be done to create an environment in which

they can thrive. Experiments that investigate the impacts of human activities on plants are critical to understanding how we can alter our habits to better protect the environment. Apart from their intrinsic value, plants provide the entire planet with an essential gas: oxygen. Many living organisms would cease to exist without plants due to their dependency on them for oxygen and food. Human activities that prevent plants from functioning properly should be studied further to observe the effects. Soils and plants that are nearby roads, driveways, highways, and parking lots are more susceptible to urban runoff from various modes of transportation and activities that occur in urban areas. There is an evident negative correlation between pollution concentrations and distance from the road (Aljazzar and Kocher 2016). Vehicles pollute land and water with contaminants such as lead, chlorine, and cyanide through gas, corroded car parts, cooling liquids, and tires. Petrochemical products, such as diesel, damage the environment and deteriorates soil quality for plants. After being exposed to diesel through the soil, Vetiver grass was shown to experience a decrease in shoots and roots (Waqar-un-Nisa et al. 2016).

Humans also cause plants unintended consequences due to pesticide and fertilizer application in both agricultural and residential settings. Pesticides have been used for thousands of years and were once natural and organic. In the 20th century, however, many harsh and synthetic pesticides were discovered and implemented into practices. They are being continually developed as organisms become resistant, which increases the ambiguous threats of pesticides (Sparks 2013). Pesticides are a cause for concern due to the impacts they have on the biological functioning of plants. It has been proven that around livestock areas, waters are polluted by pesticides as well as animal waste that disrupts whole nutrient cycles in plants (Hooda et al. 2000). Once the nutrients are incorporated into the water, they become mobile and can spread to areas far from the location of discharge. Another contaminant that affects the biological functioning of plants is herbicides. One popular herbicide is Roundup, which although effective, threatens many non-target species. It negatively impacts the compositional and functional diversity of soil microorganisms (Bruckner et al. 2019), as well as interfering with plants' internal processes. The active chemical in Roundup, glyphosate, inhibits a metabolic pathway called the shikimate pathway causing a buildup of shikimate acid in plant leaves, the acid is a useful biomarker for glyphosate (Peterson et al. 2006). The normal functioning of this pathway, however, is critical for the creation of aromatic amino acids and aromatic secondary metabolites which ultimately determine many of the plants' biological functions (Hermann and Weaver 1999). An experiment by Tesfarmarian et al. (2009) focused on sunflower seeds specifically, and showed a decrease in both the growth and biomass production of sunflower seedlings after Roundup application.

We set out to perform an experimental study to better understand the effects of different types of human pollution on the growth of sunflowers and pumpkins over time. We hypothesized that the plants watered with deionized and urban runoff would grow more in the three weeks than those watered with dilute Ortho and dilute Roundup.

METHODS

We first collected several black oil sunflower sprouts (*Helianthus annuus*, from hereafter referred to as sunflower) from the native plant garden on the SUNY Purchase College campus. We chose short, thick, and long sprouts from our collection. We then transplanted the sprouts into plastic drinking cups using Vigoro all purpose garden soil. Immediately after, we planted sunflower seeds into different plastic cups with the same garden soil. Three seeds were planted in each cup. All of the cups were then moved onto trays and placed in a plant incubator that supplied a constant light source and was maintained at a temperature of 73°F.

In order to obtain the urban runoff water, we visited the West 2 parking lot on the SUNY Purchase campus and collected water from various puddles and potholes. To make the Roundup and Ortho solutions, we used an Eppendorf reference micropipette to transfer 150µL of each solution into their own 500mL Kimax erlenmeyer flask. Each flask was then diluted with 500mL of deionized water.

We began watering the transplants and seeds daily with 40mL of each of their respective waters. After a few days of watering at 40mL, we noticed the transplanted sunflowers were struggling to absorb the water. We decided to adjust the amount of water for the transplants to 10mL increments until the soil was damp while continuing to water the seeds with 40mL each. Due to the questionable state of the transplanted sunflowers, we decided to plant pumpkin (*Cucurbita pepo*, from hereafter referred to as pumpkin) seeds during the second week of growth. The same methods were used for these seeds, except two seeds were planted in each cup instead of three. During the pumpkin seeds' first week of growth, all of the transplanted sunflowers died. This issue of data collection led us to revise the experiment to focus only on how the different types of water affect seed germination and growth.

Once a week for three weeks, we visited the incubator to measure the growth of each plant. We measured the plants in centimeters using a standard twelve inch ruler by starting from the top of the soil to the place where the stem split, also known as the first node. After we collected the data, we calculated the average height of the sprouts in each cup for both the sunflowers and pumpkins.

RESULTS

Plants watered with the urban runoff solution in the sunflower trial grew the most, with an average of 17.8 cm, over the three week data collection period. The plants watered with the control of the deionized water had the second largest average growth of 14.5 cm. The dilute Roundup and the dilute Ortho yielded similar results with averages of 9.5 and 9.8 cm respectively. Figure 1 shows the progress of the sunflower plants growth throughout the data collection period. The Roundup group consistently yielded the lowest growth, resulting in the shortest plants for the sunflower trial. The plants that received the deionized water and the urban runoff treatments both had steady and constant growth. Only the plants receiving dilute Ortho had a decrease in plant height from the highest average point of 16.9 cm down to an average of 9.8 cm.

For the pumpkin trial, the plants that were watered with the deionized water grew the most over the three week data collection period, ending at an average of 13.5 cm. The plants that were watered with the dilute Ortho had the second largest average growth of 13 cm. The third highest yield were the plants watered with the urban runoff solution with an average of 12 cm and finally, the dilute Roundup had the poorest growth with an average of 9.5 cm. Figure 2 shows the progress of the pumpkin plants over the three week data collection period. Similarly to the sunflower trial, the pumpkin plants watered with the roundup consistently yielded the lowest growth. The pumpkin plants watered with the urban runoff solution showed a decrease in height from the highest point of 12.7 cm to 12.2 cm.

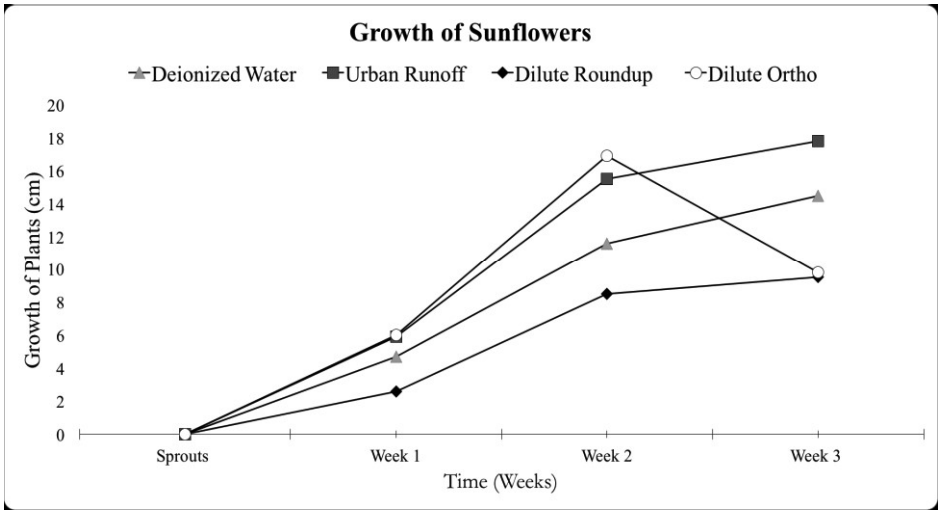

Figure 1. Growth of sunflower seeds over a three week period. Each plant was watered with deionized water, urban runoff collected from West 2 parking lot, dilute Roundup, and dilute Ortho.

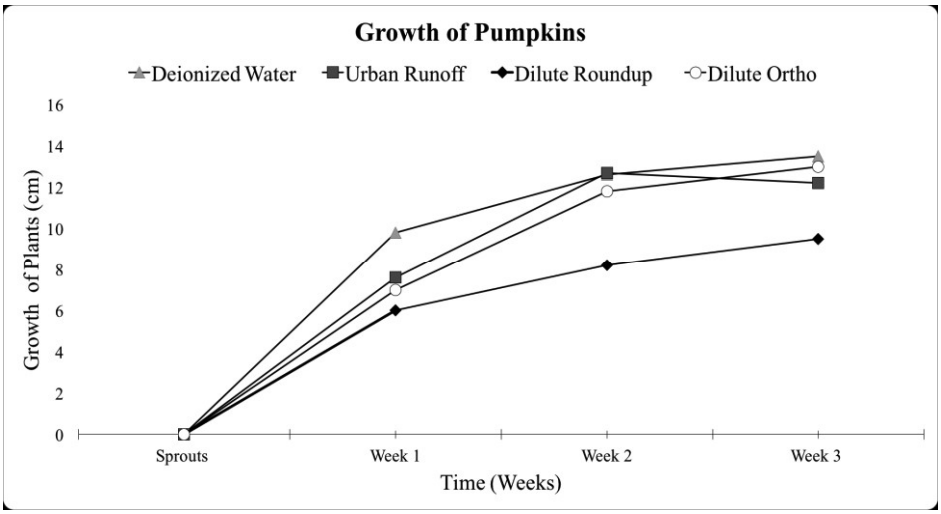

Figure 2. Growth of pumpkin seeds over a three week period. Each plant was watered with deionized water, urban runoff collected from West 2 parking lot, dilute Roundup, and dilute Ortho.

Figure 3a and 3b display the heights of the sunflower and pumpkin plants for each of the water types after 3 weeks of growth. Sunflowers watered with the control of the deionized water displayed an average height of 14.5 cm and for the pumpkins an average height of 13.5 cm. The sunflowers watered with the urban runoff solution showed an average height of 17.8 cm and the pumpkins showed an average height of 12.2 cm. The plants watered with the dilute Roundup solution showed identical average heights of 9.5 cm for pumpkins and sunflowers. Lastly, the dilute Ortho solution showed an average height of 9.8 cm for sunflowers and an average height of 13 cm for pumpkins.

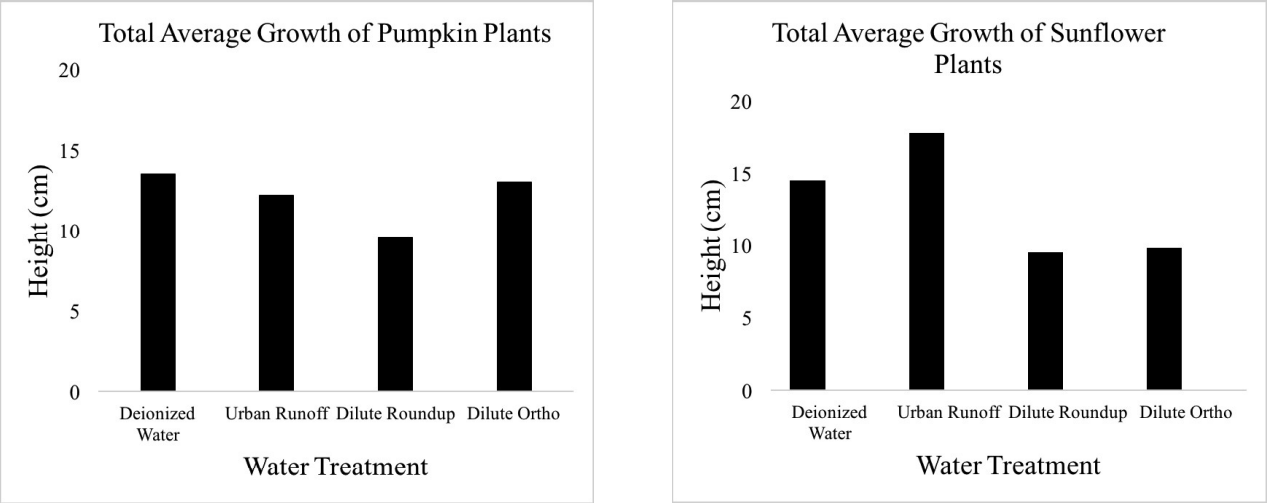

Figure 3. a) The total average growth of the sunflower plants at the end of the three week period; b) The total average growth of pumpkin plants at the end of the three week period.

DISCUSSION

Our hypothesis was that the plants that were watered with deionized water and the urban runoff would grow more than the plants watered with dilute Roundup and dilute Ortho. The purpose of this experiment was to see how human pollution has an impact on plants and their environmental growth settings. We tested this in the lab, focusing specifically on sunflower and pumpkin plants, with the goal of determining the effects of four types of water: deionized water, urban runoff, dilute Roundup, and dilute Ortho.

We noticed some puzzling trends in our pesticide results. For instance, the dilute Ortho had differing impacts on the growth of the two plant species. By the last week of measurements, the sunflowers watered with dilute Ortho had grown to a height of 9.8cm, while the pumpkins had grown to 13cm. The cause of this disparity may be explained by a difference in the genes of the sunflowers and pumpkins. Pumpkins may be more resilient to acephate, the active ingredient in Ortho which degrades rapidly in soil (Yen et al. 2000). We also noticed that the roots of the sunflowers treated with dilute Roundup were significantly shorter than all other treatments, refer to Fig 4. This is similar to an experiment done with maize, in which the same degradation of the roots occurred due to Roundup application (Gomes et al. 2019), though it is not clear exactly why the roots were impacted in this way.

Both the sunflowers and pumpkins watered with the dilute Roundup solutions showed the least amount of growth out of all of the water samples. Our findings for this were similar to the results found by Tesfamariam et al. (2009). Their research was strictly based on glyphosate, the active ingredient found in Roundup, which is easily transferred from shoots to roots and released into the soil where the microbials of glyphosate may interact with other root systems of plants. They found that on both soils they experimented on, the sunflower seedling growth and their biomass production was damaged and impaired by glyphosate treatments. However, in contrast, Silva et al. (2016) found that low doses of glyphosate can actually increase plant growth. This was not the case for our experiment, though this can offer insight as to why the plants

watered with urban runoff grew more than with the deionized water. There may have been substances in the urban runoff that we were unaware of that enhanced plant growth.

Our experiment gave us mixed results of what we predicted and future experiments can be done differently to get more uniform results. For example, due to differing findings of the effect of glyphosate and acephate on plant growth, future experiments should include multiple concentrations of each. We maintained a specific ratio of Roundup and Ortho to water throughout the experiment, though it has been found that when plants receive a concentration of pesticides above a certain level, they will experience maximum toxicity towards plant growth traits (Ahemad et al. 2012). Therefore, lesser concentrations may have beneficial effects while greater concentrations may have detrimental effects. A variety of concentrations are essential to having a more well-rounded experiment. Additionally, different types of pesticides are shown to have different degrees of impacts (Prasad et al. 2015). A study by Dhungana et al. (2016) shows variable effects of structurally different classes of insecticides on germination and early plant growth of soybean plants. Future experiments should extend the breadth of pesticides from Roundup and Ortho to include other common pesticides.

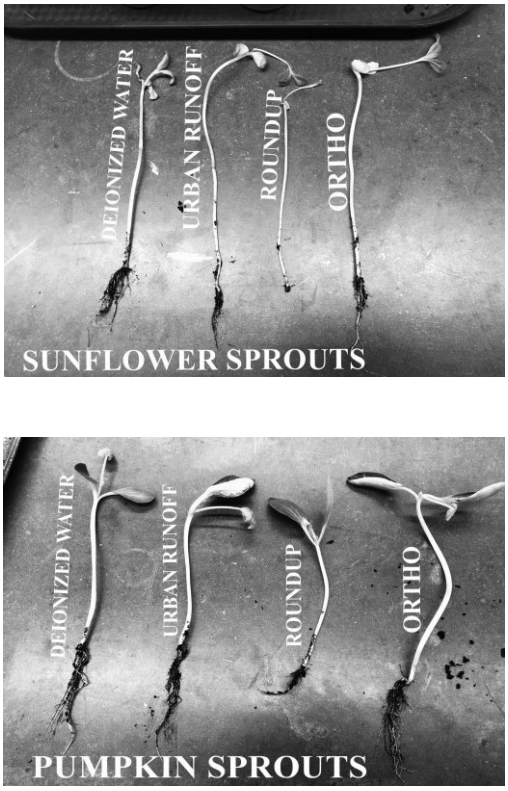

Figure 4. The effects of Roundup on the roots of sunflowers and pumpkins

Another improvement that can be made to this experiment is to more accurately measure the overall health and growth of the plants. As we measured the heights, we also took into account that many of these plants by week 2 or week 3 could not support their own weight and started to droop over the sides of the cups, in some cases causing the stems of the plants to break or wilt. We could have yielded more accurate measurements if we placed stakes into the soil and used those stakes to support the weight of the plants as they grew. Additionally, the health of the plants would be better maintained throughout the growing period if watered in small increments at a time until the soil is moist, rather than all at once. We believe the initial water doses may have been too high. Future researchers attempting this experiment should take caution in the watering amounts and rates. Lastly, when collecting urban runoff, it should be gathered from multiple locations, rather than just one. The location of collection can have an impact on how well the plants watered by urban runoff grow. Lastly, we would suggest conducting an experiment with a longer time frame to see how these plants further develop.

Human pollution through modern agricultural and industrial practices have major impacts on ecosystems and the species that inhabit them. We conducted this research experiment to study the impacts of different sources of water on the germination and growth of sunflower and pumpkin seeds. Polluted water sources from urban runoff and agricultural practices can have significant effects on the livelihood of plant species. This data, and that of future experiments, should be used towards the creation and implementation of regulations that benefit the environment and its ecosystems. These regulations would protect water and soil from harmful substances.

CONCLUSIONS

We can conclude that the presence of human pollution has impairing effects on the growth of pumpkin and sunflower seeds. There is also strong evidence from our data that shows that the herbicide, Roundup, has detrimental effects on the growth of plants by stunting their growth. This is important because it shows the negative effects that glyphosate has when it is released into an ecosystem. With this information, policies should be altered or put in place to better restrict the applications of this detrimental chemical.

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LITERATURE CITED

Ahemad, M., and M. Saghir Khan. 2012. Effects of pesticides on plant growth promoting traits of *Mesorhizobium* strain MRC4. Journal of the Saudi Society of Agricultural Sciences 11: 63-71.

Aljazzar, T., and B. Kocher. 2016. Monitoring of contaminant input into roadside soil from road runoff and airborne deposition. Transportation Research Procedia. 14: 2714-2723.

Beier, C.M., J. Caputo, G.B. Lawrence, and T.J. Sullivan. 2017. Loss of ecosystem services due to chronic pollution of forests and surface waters in the Adirondack region (USA). Journal of Environmental Management: 19-27.

Bruckner, A., A. Schmerbauch, L. Ruess, F. Heigl, and J. Zaller. 2019. Foliar Roundup application has minor effects on the compositional and functional diversity of soil microorganisms in a short-term greenhouse experiment. Ecotoxicology and Environmental Safety. 174: 506-513.

Dhungana, S.K., I.D. Kim, H.S. Kwak, and D.H. Shin. 2016. Unraveling the effect of structurally in different classes of insecticide on germination and early plant growth of soybean [*Glycine max* (L.) Merr.]. Pesticide Biochemistry and Physiology 130: 39-43.

Gomes, M.P., 2019. Effects of Ciprofloxacin and Roundup on seed germination and root development of maize. Science of The Total Environment. 651: 2671-2678.

Hermann, K.M., and L.M. Weaver. 1999. The Shikimate Pathway. Annual Review of Plant Physiology and Plant Molecular Biology 50: 473-503.

Hooda, P.S., A.C. Edwards, H.A. Anderson, and A. Miller. 2000. A review of water quality concerns in livestock farming areas. Science of the Total Environment: 143-167.

Petersen, I.L., K.E. Andersen, J.C. Sorenson, and H. Sorenson. 2006. Determination of shikimate in crude plant extracts by micellar electrokinetic capillary chromatography. Journal of Chromatography A: 253-258.

Prasad, S.M., A. Singh, and P. Singh. 2015. Physiological, biochemical and growth responses of Azolla pinnata to chlorpyrifos and cypermethrin pesticides exposure: a comparative study. Chemistry and Ecology 31: 285-298.

Schipper, P.N.M., R.N.J. Comans, J.J. Dijkstra, and L. Vergouwen. 2007. Runoff and windblown vehicle spray from road surfaces, risks, and measures for soil and water. Water and Science Technology 55: 87-96.

Silva, F.M.L., S.O. Duke, F.E. Dayan, E.D. Velini, and P. Kudsk. 2016. Low doses of glyphosate change the responses of soybean to subsequent glyphosate treatments. Weed Research 56: 124-136.

Tesfamarian, T., S. Bott, I. Cakmak, V. Romheld, and G. Neumann. 2009. Glyphosate in the rhizosphere—Role of waiting times and different glyphosate binding forms in soils for phytotoxicity to non-target plants. European Journal of Agronomy 31: 126-132.

Waara, S., and C. Färm. 2008. An assessment of the potential toxicity of runoff from an urban roadscape during rain events. Environmental Science and Pollution Research International 15: 205-210.

Waqar-un-Nisa, B. Nazneen, A.R. Saleem, A. Rashid, and L. Dawson. 2016. Effect of diesel contamination on the physico-chemical characteristics of soil and growth of vetiver grass. Soil and Environment 35: 91-98.

Yen, J.H., K.H. Lin, and Y.S. Wang. 2000. Potential of the insecticides acephate and methamidophos to contaminate groundwater. Ecotoxicology and Environmental Safety. 45: 79-86.