Implications of Microplastic Pollution on Green Bean Growth and Production

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Abstract

The implications of microplastic pollution on varying ecosystems and the organisms within them have become an area of concern and major research focus. The presence of microplastic pollution within soils has the ability to alter some soil characteristics, as well as plant growth. This study assessed the effects of microplastic polluted soil on green beans (*Phaseolus vulgaris)* grown within a greenhouse. Control and polluted green beans were grown in the same conditions, except for the microplastic mixture added to the experimental group. After the beans fully germinated, shoot length, bean production, and produced bean weights were recorded. Although the data between the two groups did not vary significantly, this study used an organism familiar to a wide scope of people. In general, our results were not consistent with published data, in that the polluted group did not display positive or negative implications as a result of the pollutant's presence. Additionally, the need for further research using a variety of organisms as well as selected variables was highlighted.

Introduction

Microplastics have become increasingly abundant, and infiltrated a variety of food webs which is leading to the death of many organisms due to biomagnification. The impact of this pollutant became more apparent with the Great Pacific Garbage Patch, which is a vast collection of debris located in a system of rotating ocean currents. In 2017, this site was estimated to contain a conservative estimate of 42,000 metric tons of microplastics of varying sizes (Lebreton et al., 2018). While this draws attention to an important issue, especially considering that the United States produced a total of 32 million tons of plastic waste in 2012 alone, it fails to acknowledge the scope of this type of pollution (McGuire et al., 2015). Microplastics are broadly defined as mixed plastics that are 5mm or smaller in diameter, such as fibers, granules, and fragments. Particles can be classified into two groups based on their source. Primary microplastics are created directly for use within manufacturing, while secondary microplastics result from fragmentation of larger plastic pieces (Guo et al., 2020). Currently, the research available into this pollutant's effects within different environments varies largely according to accessibility and public interest. While in the past few years, published data focused primarily on aquatic ecosystems, there has been a shift in current research that now encompasses a wide array of organisms and environments. Data have been published that demonstrate the extent of this pollutant's presence within soils (Zhu et al., 2019). The exact level of soil contamination cannot be determined or quantified due to the vastness of soils. However, relative abundance can be generally estimated when considering the scale at which single-use plastics are disposed of: it was estimated that 300 million tons of plastic had been synthesized in 2017 (Wang et al., 2019).

While these plastics are a concern for aquatic environments, a large portion of them end up in landfills and eventually in terrestrial ecosystems. There are a multitude of ways that microplastics can end up in soils. Around two-thirds of produced microplastics result from tire runoff and washed garments (Boucher & Friot, 2017). The scale of washed garment pollution can be demonstrated by the fact that washing one pair of jeans results in around 56,000 microfibers being released (Athey et al., 2020). Tire runoff occurs over time when any vehicle is driven, due to the high amount of friction that occurs from the tires' tread pattern. This results in tiny pieces of synthetic rubber being flung from the tire, which then enters the surrounding environment (Tamis et al., 2021). Everyday cosmetic products used to be a significant source of microplastic pollution, but in 2015 the Microbead-Free Waters Act was established in the United States. This prohibited the inclusion of microplastics in rinse-off cosmetics such as exfoliators and toothpaste (Microbead-Free Waters Act, 2015). This statute demonstrates a positive shift towards the regulation of these harmful pollutants.

Wastewater treatment plants, which do not regulate the output of microplastics in the recycled water and sewage sludge they produce, are a major source of microplastics in agriculture. While there are ways to reduce the number of microplastics that leave the facility, there is currently no standard protocol widely utilized by these plants (Bretas et al., 2020). Sewage sludge, which is semi-solids produced as a byproduct of wastewater treatment, are commonly applied to soils to act as a fertilizer. In Europe and North America alone, fifty percent of produced sewage sludge is applied as a fertilizer, which leads to an estimated 110,000 to 730,000 tons of microplastics being transferred into the soil annually. Application of microplastic polluted fertilizer is something that could be reduced or regulated with more knowledge about how it is negatively impacting ecosystems ("Effects of microplastics," 2016)

Additionally, agricultural practices such as the use of plastic mulch or slow-release fertilizers can account for introducing this pollutant to soils over time (Hurley & Nizzeto, 2018). Despite the rising popularity of these products, many fail to realize the long-term negative effects that can occur. The introductory sources of microplastics into terrestrial ecosystems span from agricultural practices to everyday tasks and demonstrate how reliant we have become on plastic usage in modern times.

Organisms found within the soils are not immune to the impacts of pollutants in these ecosystems. Plants comprise a large portion of many people's diets, thus all potential pollutants need to be explored to understand if they will impact those consuming produced crops. Oliveri Conti et al. (2020) quantified the presence of microplastics within an array of store-bought produce and found it to be present in apples, pears, carrots, lettuce, potatoes, and broccoli, with the apples and pears showing the highest quantification of microplastics. Aside from this pollutant being present in fruits, it can also have negative impacts on the commercial profit of crops and soil ecosystems. Studies using spring onion and perennial ryegrass found that there was a change in total plant biomass as well as seed germination rates (Boots et al., 2019; de Souza Machado et al., 2019). These findings indicate that the presence of microplastics in soil could lead to reduced crop yields overall. Other recent studies focus on the phytotoxicity of this pollutant, and how it may affect agroecosystems. Some plant groups, such as wheat, lettuce, and broad beans do not respond to the pollutant well, while others such as onions can tolerate it. Since the presence of microplastics in soils is able to alter soil physical properties, such as *p*H and bulk density, it may lead to affected nitrogen and phosphorus cycling (Iqbal et al., 2021). Currently, available research supports microplastics being a harmful pollutant and having varying effects on plants based on which species is being assessed and the size and quantity of the pollutant.

Based on the currently published data regarding microplastic pollution's impacts on varying plant species, we hypothesized that if green beans (*Phaseolus vulgaris*) are grown in microplastic polluted soils, then they will display altered rates of shoot length, bean production, and bean weight compared to the control group.

Methods

Setup

'Burpee's Stringless Green Pod' heirloom beans were grown in 6-inch standard pots filled with potting soil. Before placing the seeds in the pots, 1/2 teaspoon (tsp) gypsum, 1 tsp milorganite, 1/4 tsp triple superphosphate, 1/4 tsp STEM (Soluble Trace Element Mix), 1/2 tablespoon dolomite, and 1/4 tsp Epsom salts were added and gently mixed in by hand. After the beans sprouted, which took one week, 1/2 tsp K-Mag was added to each pot. These fertilizers guaranteed that the plants had adequate levels of nutrients to grow successfully. Every container also received a few granules of Burpee Bean & Pea Booster to ensure that the plants had the necessary *Rhizobium* bacteria to properly fix nitrogen. After approximately one month of growth, a commercial imidacloprid mix (Prokoz Zenith™ 2F) was applied according to the manufacturer's protocols, to eradicate a small whitefly infestation that had developed. The pots were placed in partial sun within the greenhouse and watered by hand when the soil became dry.

Each pot initially received three beans, and the weakest of these was removed after twelve days if applicable. The weakest plants were those that were not growing as successfully or appeared to be stunted in comparison to the other plants in the pot. Each treatment consisted of 30 pots, and all variables between the groups were consistent except for added pollutants. The experimental group received a tsp of a microplastic mixture prior which was gently mixed into the top few inches of soil with the previously mentioned nutrients prior to seed placement. The mixture included small plastic beads (5 mm), micro-glitter, and broken-up styrofoam.

Data Collection

Measurements for shoot length, number of beans produced, and weight of beans produced for green bean plants in both the control and microplastic polluted soil groups were collected after forty-seven days. Beans that did not successfully grow, thus not fruit as well, were removed from the dataset before statistical analysis was run. The beans produced and weighed were ones determined to be of commercial value, thus any small/immature beans were not included.

Statistical Analysis

Average shoot length, number of beans produced, and produced bean weights was calculated by summing the shoot length per group and dividing by the respective total number of plants. This was repeated for the produced beans, as well as bean weight, with the total weight being divided by the total number of beans. We arranged visual comparisons of shoot length and total produced beans as well as the average of each variable between the control and experimental group.

Collected data were used in a 2-sample T-test conducted for shoot length, total beans produced, and the weight of these beans. These statistics include the mean, standard deviation, 95% confidence interval, and the P-value for each group.

Results

Microplastics have the ability to impact a variety of soil characteristics as well as the plants present within this ecosystem. Thus, green bean growth within microplastic polluted soils was assessed in regards to shoot length, bean production, and total bean weight. Green bean growth within microplastic polluted soils were not significantly different from the control in regards to shoot length (P-value 0.413), bean production (P-value 0.444), and total bean weight (P-value 0.376).

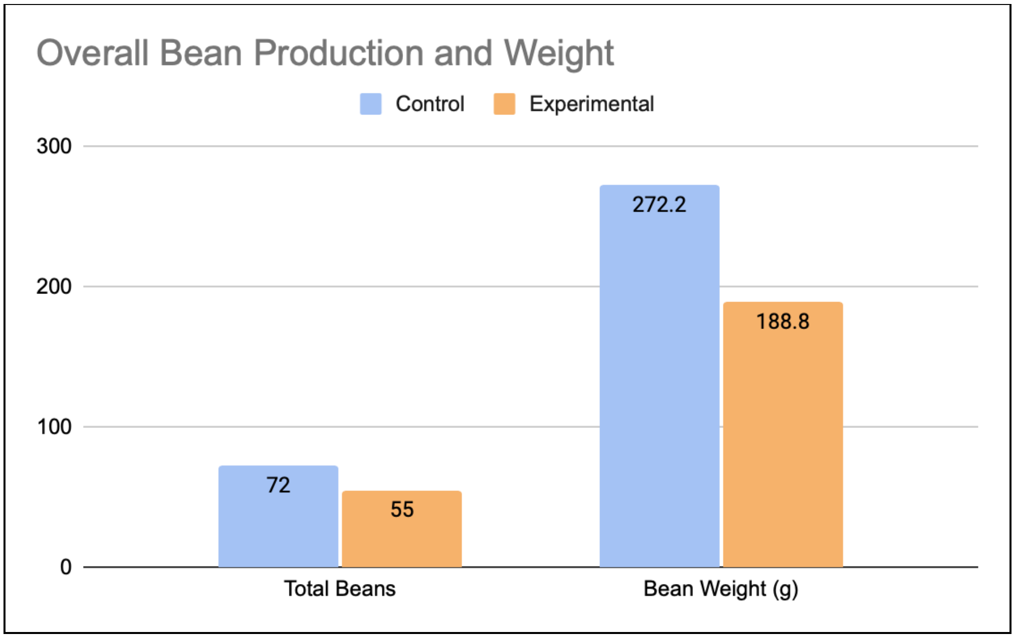

Figure 1: A visual representation of the total produced number of beans, and weight for the control and experimental group.

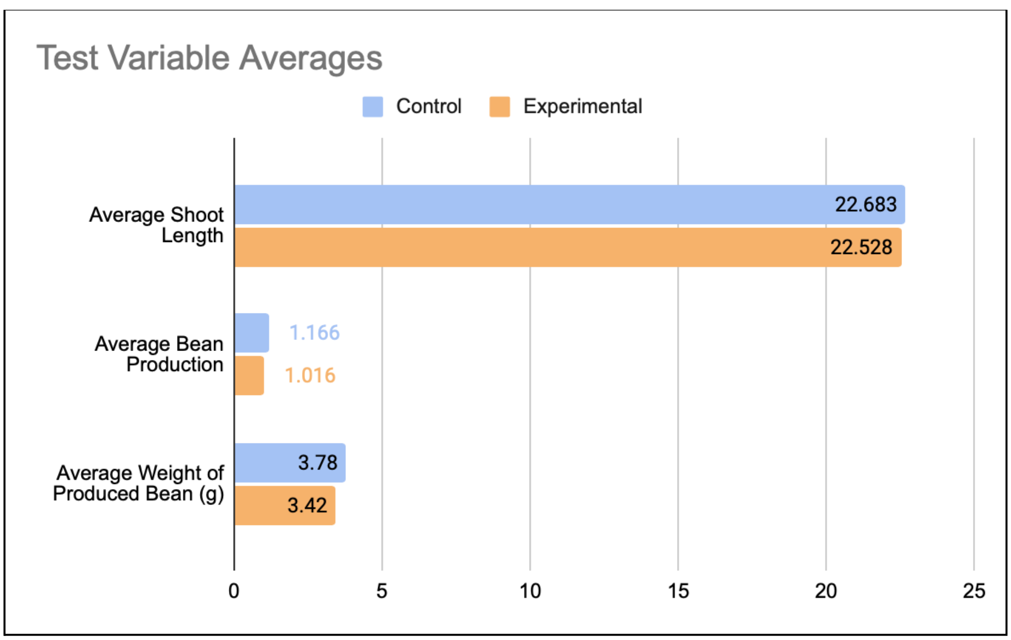

Figure 2: A visual representation of the average shoot length, bean production, and bean weight for each group.

Figure 3: The layout of the control and experimental green bean plants grown within a greenhouse.

Two-Sample T-Test and CI: Shoot length control, Shoot length MP

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
Shoot length control	58	24.50	6.24	0.82
Shoot length MP	57	23.71	6.00	0.80

Estimation for Difference

Difference	95% CI for Difference
0.79	(-1.48, 3.05)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
0.69	112	0.493

Figure 4: Descriptive statistics, 95% Confidence Interval, and 2-Sample T test of shoot length between the control and experimental group

Two-Sample T-Test and CI: control beans produced, MP beans produced

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
control beans produced	58	1.21	1.10	0.15
MP beans produced	57	1.07	1.03	0.14

Estimation for Difference

Difference	95% CI for Difference
0.137	(-0.258, 0.532)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
0.69	112	0.494

Figure 5: Descriptive statistics, 95% Confidence Interval, and 2-Sample T test of bean production between the control and experimental group

Two-Sample T-Test and CI: green bean weight C, green bean weight MP

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
green bean weight C	58	4.65	4.10	0.54
green bean weight MP	57	3.32	3.77	0.50

Estimation for Difference

Difference	95% CI for Difference
1.336	(-0.118, 2.790)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
1.82	112	0.071

Figure 6: Descriptive statistics, 95% Confidence Interval, and 2-Sample T test of produced bean weight between the control and experimental group

Discussion

Microplastic pollution has become a more prevalent issue as its presence in nature has increased. While it is difficult to determine the extent of microplastic soil pollution, multiple studies demonstrate the presence of this pollutant within terrestrial ecosystems (Zhu et al., 2019). Current research shows varying effects on plants when this pollutant is present within soils. Thus, there is further need to study and assess how this pollutant impacts a wide range of plant species as well as differing types of microplastics.

While some studies have displayed the varying impacts that microplastic pollution has on plants, the results of this study indicate that there is no significant difference between the microplastic affected and control group. The presence of microplastics was found and quantified in a range of fruits, which was unlike the findings within this study (Oliveri Conti et al., 2020). This could be due to the scale at which the sampled fruit were grown, or even the differences in study organisms. Additionally, studies have displayed that seed germination rates and total plant biomass can be altered with the presence of this pollutant (Boots et al., 2019; de Souza Machado et al., 2019). While the total number of produced beans, bean weight, and the average weight of a bean from each group appear to differ (Figures 1-2), there was no significant difference. This was demonstrated by the P-values (Figures 3-6). This probably resulted from the type and concentration of microplastics utilized, which current research demonstrates as an determining factor in how plant growth is impacted. These characteristics, as well as microplastic shape, can determine whether plant performance is positively or negatively impacted (Lozano et al., 2021). While the findings of this study may not be considered significant, they utilize a study organism common in daily life, as well as demonstrate the need for further research concerning this pollutant.

In future trials, small changes should be made to improve efficiency as well as the significance of the data. If a reliable irrigation system were accessible, this would ensure that every plant would receive equal amounts of water throughout the course of the experiment. Controlling the growth environment would be valuable in that it could aim to eliminate pest infestations which would reduce the chance of harmful insects skewing the collected data. Adding stakes to the plants may be beneficial as well, as the closeness of the pots shown in Figure 3 can be used to explain how the plants became tangled together as they matured. Another aspect that could be improved is sample size, as larger sample sizes yield a more representative population and thus more accurate results. Finally, if the budget permitted, smaller and more uniform microplastics could be used that would hopefully yield the desired results of this experiment. This would mirror the design of previously mentioned successful studies.

Most current research concerning the implications of microplastic pollution on plants analyzes commonly consumed plants. While this is logical because these plants directly affect the organisms consuming them, plants consumed by organisms other than humans also need to be considered. The way that this pollutant interferes with or alters varying aspects of plant growth could also be altering the natural roles and functions of ecosystems. Microplastic pollution has become an increasingly popular area of concern and study. This subject is shifting slowly to encompass a variety of ecosystems from marine to terrestrial, and will eventually discuss multiple trophic levels as well, as this is vital to understanding how this man-made pollutant is impacting the natural world at all levels.

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