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Decomposition of Horse Manure in Three Soil Media and the Implications of Manure Leachate for the Germination of Radish Seeds

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ABSTRACT In this microcosm study we examined the decomposition of horse manure in three substrates: potting soil, wood mulch, and sand. Microcosms consisted of a sample of horse manure placed in a small leachable chamber, containing one of the three substrates. Mulch promoted the greatest mass loss. Leachate collected by irrigating each microcosm with distilled water was used to germinate radish seeds. Only the leachate from microcosms in which manure decomposed in potting soil promoted greater radish radicle growth compared to the controls in which no manure was placed. The implications of these results for the design of a soil-based decomposing system – specifically “The BioShaft,” designed by Domenico D'Alessandro – are discussed.

INTRODUCTION

Efficiently removing human fecal waste from homes, businesses, and schools with hopes of reducing the risk of disease is a primary goal of sewage infrastructure. Modern day sewer systems arose in the Victorian era when illnesses such as typhoid and cholera were prevalent, although other infrastructure, including open drains, predates this (John Blake Associates, 1993). Concerns about disease remain valid. Nonetheless, modern sewage systems can still end up contaminating sources of drinking water as well as rivers and seas, contributing to their pollution. This is because we commingle

excremental waste with water rather than decomposing waste in the soil, as more regularly occurs in natural terrestrial ecosystems. In addition, sewage systems are inefficient in their use of energy and water use. They use tremendous amounts of energy to pump dirty water through the system while the average US household uses 70,000 gallons of fresh water per year to flush less than 500 pounds of excrement (John Blake Associates, 1993).

In recent decades, several more cost and energy efficient waste management systems have been proposed, most notably the dry composting toilet. This system works in a similar way to general composting, in which organic waste goes through controlled aerobic decomposition into a stable and sanitized end-product that can

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safely be applied to land (Hill, 2013). Dry composting toilets can do this with human excrement in addition to other organic wastes. Recent studies have illustrated success in the implementation of composting toilets in developing countries where sanitation is especially a concern (Henry, Olsen, & Fioravanti, 2009). Because composting toilets are generally larger than standard toilets, they are more suited to areas with the space to accommodate them. As such, other approaches must be explored to create such an efficient waste management and recycling system in urban areas where space is often more limited.

The BioShaft project is one such approach. The project was conceived by Chicago-area designer Domenico D'Alessandro. The BioShaft is a soils-based treatment system for the decomposition of human fecal waste. The technology is similar to composting, but when fully developed will be attached as an enclosed soil column outside of a building. Thus blackwater including fecal waste would be sent to the column as a toilet is flushed and decomposed in the soil within the column. The nutrient-rich leachate resulting from the irrigation of the decomposing fecal waste can then be used as a plant fertilizer.

Little research exists on the decomposition of feces – horse, human or otherwise – in the variety of substrates than can be used in the BioShaft. The focus of this study was thus to quantify and compare the percent decomposition of feces in different soil types in order to determine the ideal soil type to be used in the BioShaft prototype. The ideal substrate for the BioShaft will combine a high decomposition potential with low density. In this way it will reduce the weight of the BioShaft, and alleviate stress on building infrastructure.

To reduce the hazards associated with conducting this research we used horse manure as a surrogate for human feces. The effectiveness of the leachate from each soil type to grow plants was assessed using the germination of radish seed.

OBJECTIVES

Our objective was to determine which of the following three soil substrates: potting soil, sand, or wood-mulch facilitated the greatest mass loss of horse manure. Additionally, we wanted to determine if leachate from these systems had a differential effect on the germination and early growth of plant seedlings. Another objective was to establish if our microcosm system (described below) is suitable for long-term research on this topic.

METHODS

A Nalgene rapid flow 90 mm/1000 ml disposable filter system was used as a microcosm. Each filter system comes with a 1000 ml chamber in which we placed the substrate along with a known quantity of dung. This chamber is secured above a collecting vessel in which leachate can be collected.

The Nalgene chamber contained one of three substrates for decomposition: sand, mulch, and potting soil. There were four replicate microcosms per substrate. These substrates represent the potential materials to be used in the BioShaft project. A known quantity (approximately 12g dry weight) of horse manure was weighed and placed within each microcosm. Deionized water was used to maintain a constant moisture level in the microcosms. Three controls were constructed in the same way as all other microcosms but did not contain horse manure.

All microcosms were maintained in a Class II, Type A2 Biological Safety Cabinet. The microcosms were established on 9 October 2015 and the experiment concluded 12 January 2016.

In the last week of the experiment, the microcosms were irrigated with 500 ml of deionized water. The leachate was used to grow radish seeds. Seed growth was monitored by measuring radicle growth of each seedling. Radish seedlings were placed on filter paper in petri dishes and left in a dark room for a week after irrigation with 10ml of leachate. In all, five radish seeds per microcosm were germinated. Each seed was irrigated with 10 ml of the leachate. After five days, radicle growth was measured.

At the end of the experiment, the microcosms were destructively sampled and the final mass of the manure was measured. Decomposition was measured as the standardized differences in mass at the beginning and end of the experiment and represented as percent mass loss (Fig. 1).

Differences in mass loss of horse manure in the three substrates were analyzed using a one-way analysis of variance (ANOVA). Effects of leachate on the germination of radish seeds were analyzed using t-tests to contrast leachate of each substrate against the soil control (without manure.)

RESULTS

Mass loss of manure over the 95-day experimental period was greatest in mulch, followed by potting soil, and both facilitated higher percent decomposition than sand (ANOVA, $p < 0.05$, see Figure 1).

Figure 2 shows radish radicle extension was significantly different between the control potting soil and manure in soil ($p = 0.05$), whereas there was no difference between mulch and sand and their respective controls ($p = 0.33$, 0.27 respectively).

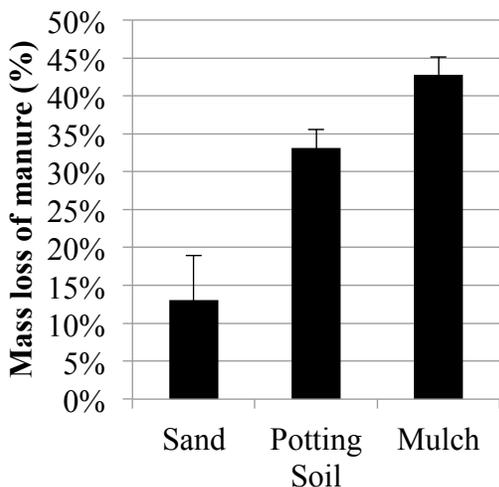


Figure 1. Mean mass loss (%) of horse manure associated with three different substrates (bars representing ± 1 standard error).

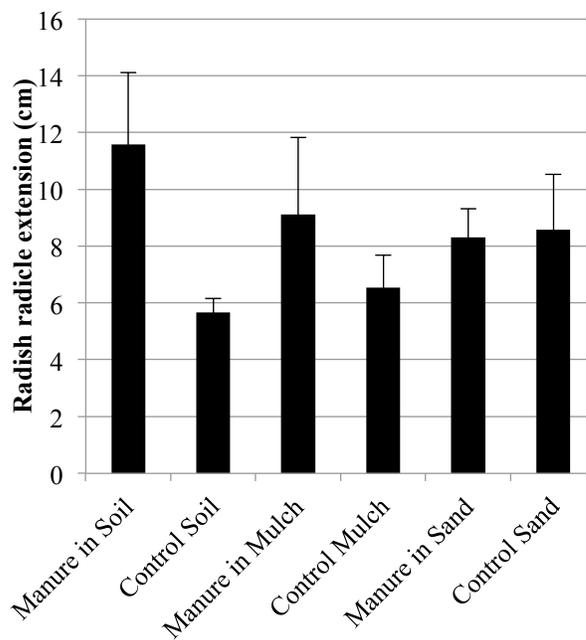


Figure 2. Five-day radish extension compared to substrate controls (bars representing ± 1 standard error).

DISCUSSION

The data shows that the horse manure samples decomposing in mulch had the greatest percent mass loss, followed by soil and then by sand. This is an encouraging result for the BioShaft design, since it suggests that a relatively lightweight organic material can outperform soil as a medium for the breakdown of fecal matter. Mulch is a good medium for the growth of microbial communities and these communities are ultimately responsible for decomposition.

We expected that the medium promoting the most rapid decomposition would also produce leachate that would encourage the greatest radicle growth in radish seeds. This is because we assumed that more decomposition would lead to more nutrients in the resulting leachate. This was not the case, however. There was no significant difference found between the control and experimental mulch leachate, and differences in radicle extension across the experimental leachates were insignificant. This suggests that adding the horse manure to the mulch did not significantly affect nutrient load

in the leachate (which would have contributed to radicle extension). Where there was a significant difference was between the experimental and control leachates from the potting soil microcosms - the control had a significantly smaller average radicle length than the

experimental. This suggests that for the potting soil, the addition of horse manure positively affected the available nutrients in the resulting leachate.

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