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Examining the effect of soil potassium level on sugar content in radishes (Raphanus Sativus)

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Introduction

Soil macronutrients are one of the many factors essential to facilitating an optimal environment for plants to grow. The three essential macronutrients, nitrogen, phosphorous, and potassium, are frequently used as fertilizers since, after uptake from the plant's root system, they are distributed throughout the organism and used for various metabolic, osmotic, and energetic processes (Amtmann and Blatt 2009). Potassium in particular has been associated with higher turgor pressure, a measure for general plant health, as well as enzyme activity related to photosynthetic processes and therefore increased quantities of the primary photosynthetic products: oxygen and glucose (Sigel et al. 2016). Additionally, even more than nitrogen or phosphorous, potassium has been shown to relate to higher fruit quality in plants (Spironello et al. 2004).

One way to introduce macronutrients into soil is via compost. To prepare compost, organic matter is decomposed either into a base of soil or pre-made compost. This can provide a nutrient-rich environment for plants to grow since food scraps and yard waste, common compostable items, provide extra essential micro and macronutrients to help condition and fertilize the soil (Khater 2015). Bananas are fruits that contain a high potassium content, and they are quick to decompose, so composting them will likely create a soil environment that contains high levels of potassium.

Sugar refractometry is a technique that is often used as a measure for fruit or vegetable quality. The Brix scale was developed to indicate the level of soluble solids in a solution and is measured in degrees, with 1 degree Brix corresponding to 1 gram of sugar in 100 grams of solution (Kleinhenz 2012). A higher °Brix relates to a higher sugar content and therefore a higher overall fruit or vegetable quality. In this study, radishes (*Raphanus Sativus*) were studied for their relatively low °Brix value since any change in this would be easy to observe (Rodriguez-Saona et al. 2001). They also tend to grow quickly and there are two areas on the plant that can be checked for a Brix reading: the bulb and the leaf, just in case the bulbs do not grow large enough to get a reading from the sugar refractometer.

Since potassium increases enzyme activity related to photosynthesis and one of the primary products of photosynthesis is glucose, it stands to reason that increased soil potassium levels (via compost) will correspond to increased sugar content and therefore a higher °Brix value. However, this relationship may not be linear due to a multitude of complex community interactions that occur in a soil environment. Compost, although useful for conditioning and fertilization, may facilitate growth of competing species like fungi and bacteria in the soil (Kertesz and Thai 2018). Despite these factors, we predict that compost will increase the °Brix of radishes when compared to radishes grown in a control soil environment.

Methods

Procedure

We began by heating bananas in a drying oven overnight in order to increase the rate of the decomposition process. Then, we shredded the bananas and dispersed them in soil before allowing them to decompose. After 5 days of decomposition, we autoclaved the compost and planted two experimental groups of radish seeds: one in the banana compost and one in control soil with no bananas added. Potassium levels of each soil were tested using a soil test kit. Every day for 23 days after planting, we tested soil moisture levels, watered radishes if needed to maintain optimal moisture level, and rotated containers under heat lamp to ensure even light and heat to both groups. Every four days, apical meristem height was measured. A black fly infestation occurred so a pesticide was added to compost radishes and fly traps were placed by both containers. After 23 days, we harvested the radishes early due to the infestation and tested the °Brix using a sugar refractometer. Root length and radish mass were measured after harvesting and soil nitrogen/phosphorous levels were measured using a soil test kit to ensure that they were not confounding variables.

Statistical Analysis

A two-sample t-test test was run on the data in RStudio to examine the effect of soil potassium content on sugar content in radishes. A Wilcoxon rank sum test was also run in RStudio to look at the effect of soil potassium content on radish mass and a two-sample t-test was run in RStudio to examine the effect of soil potassium content on radish root length. Finally, a 2-way ANOVA followed by two-sample t-tests were run on the data in RStudio to examine the effect of soil potassium content on apical meristem height at three different time points.

Results

Compost had a significant negative effect on the °Brix of the radish bulbs when compared to the control soil (2-sample t-test: $t = -2.60$, $df = 37$, $p = 0.013$). The mean ± SE °Brix of radishes grown in control soil was 4.90 ± 0.10 and the mean ± SE °Brix of radishes grown in compost was 3.73 ± 0.53, showing a 1.17° decrease and a 27.1% difference when compared to radishes grown in compost (Figure 1).

Compost also had a significant negative effect on the mass (g) of the radishes (Wilcoxon rank sum test: W = 5, $p < 0.001$). Radishes grown in control soil had a mean ± SE mass of 9.01 ± 0.65 and showed a 151% difference in mass when compared to radishes grown in compost which had a mean ± SE mass of 1.25 ± 0.39. (Figure 2).

In addition, radish root length (cm) was also significantly negatively impacted by compost (2-sample t-test: t = -3.38, df = 44, p = 0.002). The mean ± SE root length for radishes grown in control soil was 11.67 ± 0.50 cm and the mean ± SE root length for radishes grown in compost was 8.85 ± 0.76, showing a 27.5% difference between the two groups (Figure 3).

Apical meristem height was measured at three time points and the effect of soil type on apical meristem height depended on the date of measurement (2-way-ANOVA: F = 51.98, df = 2, $p < 0.001$). At time point 1, apical meristems of radishes grown in compost (2.54 ± 0.15 (SE) cm) were 25.4% lower than apical meristems of radishes grown in control soil (3.28 ± 0.27 (SE) cm) (2-sample-t-test: t = -2.41, df = 46, p = 0.02). At time point 2, apical meristems of radishes grown in compost (4.36 ± 0.32 (SE) cm) were 72.3% lower than apical meristems of radishes grown in control soil (9.31 ± 0.46 (SE) cm) (Wilcoxon rank sum test: W = 14.5, $p < 0.001$). The trend in the data continued at time point 3 when apical meristems of radishes grown in compost (5.67 ± 0.72 (SE) cm) were 103.8% lower than apical meristems of radishes grown in control soil (17.92 ± 0.73 (SE) cm) (Wilcoxon rank sum test: W = 8.5, $p < 0.001$). At all time points, apical meristems of radishes grown in compost were significanty lower than radishes grown in control soil but this difference increased in magnitude as time progressed (Figure 4).

Compost radishes showed signs of the disease black root rot as fungus appeared to grow in their container. This led to a mortality rate of 29% in compost radishes compared to a 0% mortality rate in radishes grown in control soil.

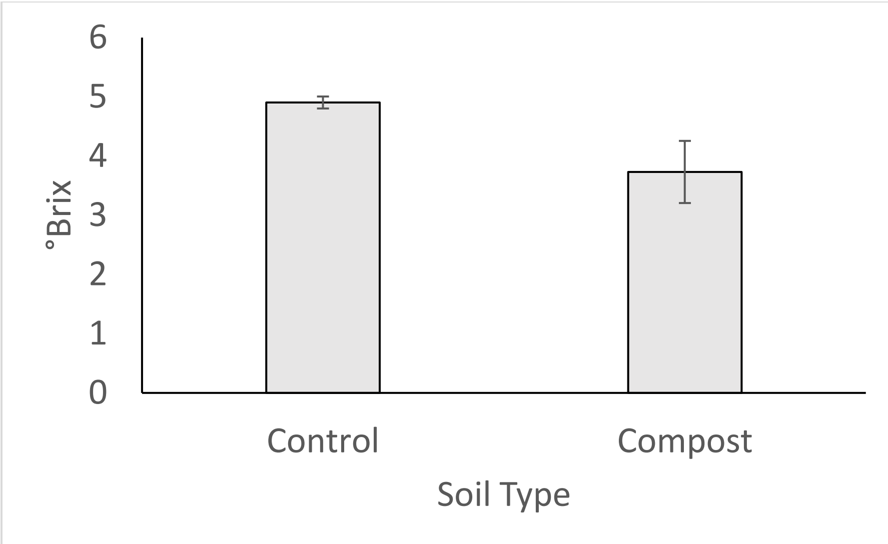

Figure 1. °Brix (mean ± SE) in radishes grown in compost (n=24) and radishes grown in control soil (n=24). Compost had a significant negative effect on °Brix of radishes (t-test: $p = 0.013$).

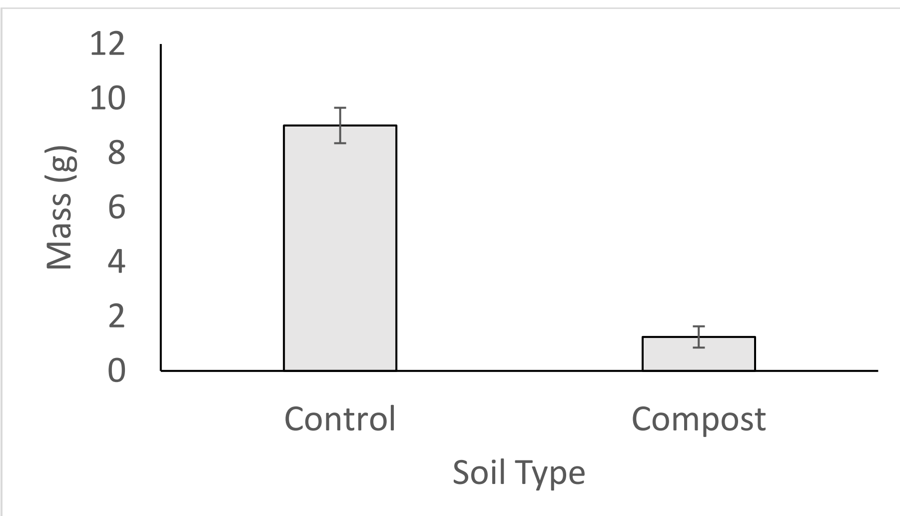

Figure 2. Mass (g) (mean ± SE) in radishes grown in compost (n=24) and radishes grown in control soil (n=24). Compost had a significant negative effect on mass of radishes (Wilcoxon rank sum test: $p < 0.001$).

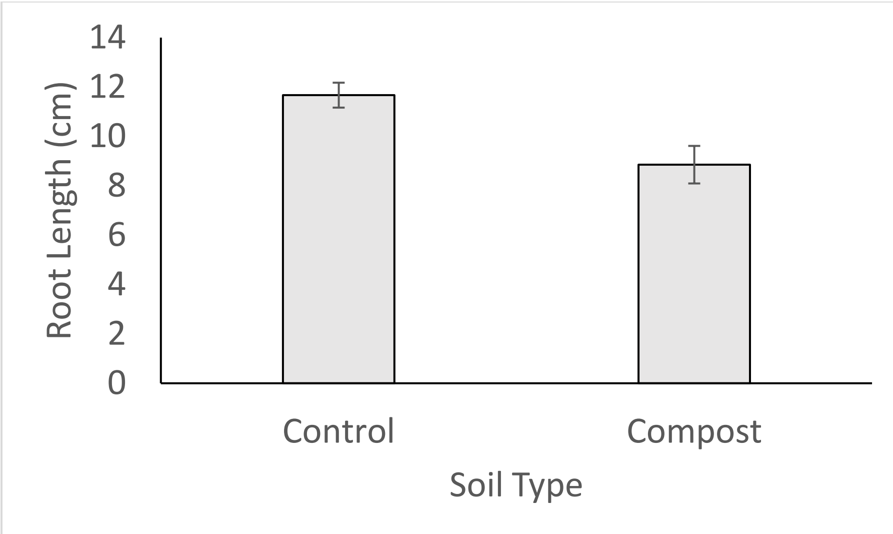

Figure 3. Root length (cm) (mean ± SE) in radishes grown in compost (n=24) and radishes grown in control soil (n=24). Compost had a significant negative effect on root length of radishes (t-test: $p = 0.002$).

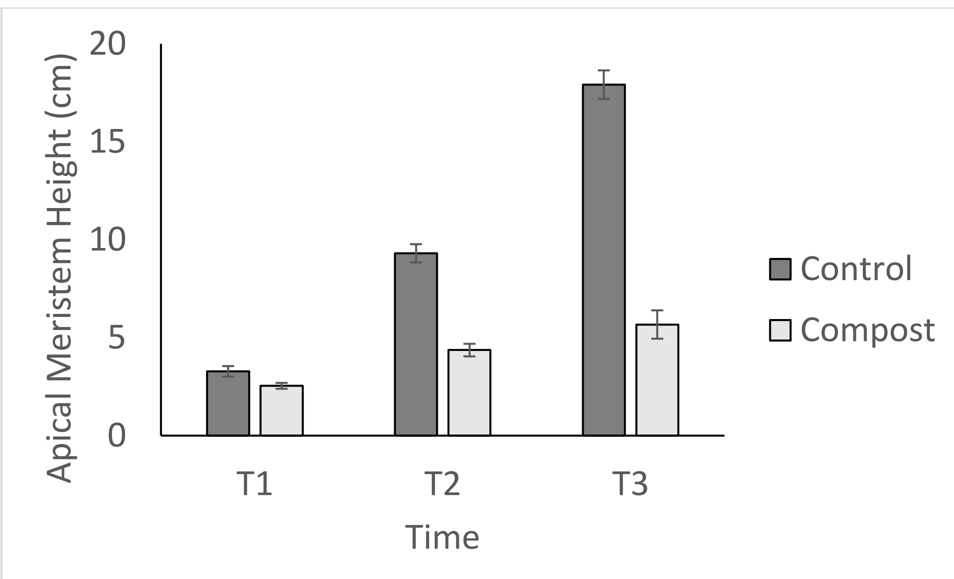

Figure 4. The effect of soil type on apical meristem height was dependent on time point (2-way ANOVA, $p < 0.001$). At time point 1, compost slightly decreased apical meristem height (t-test, $p = 0.02$). At time point 2, compost slightly moderately decreased apical meristem height (Wilcoxon rank sum test, $p < 0.001$). At time point 3, compost greatly decreased apical meristem height (Wilcoxon rank sum test: $p < 0.001$).

Discussion

The results of this study did not conform to our hypothesis. Instead of increasing sugar content, increased levels of potassium decreased the °Brix of radishes. Not only did the increased potassium environment have a negative effect on sugar content, but it also negatively impacted measures indicating growth and development such as mass, root length, and apical meristem height of the plants. Overall, the data show a clear trend that the compost with increased potassium levels had a negative effect on all metrics of plant health and vegetable quality measured.

Our result conflicts with the findings of many similar studies. For example, Bedsford and Maw found a distinct positive relationship between soil potassium concentration and the growth rate of tomato plants (1975). Results of other studies not only conflicted with our findings regarding plant growth, but they also found that fruit quality (indicated by sugar content among other factors) increased with greater soil potassium content (Lester et al. 2010). Since °Brix can be a proxy for fruit or vegetable quality, these studies differ with our results that higher potassium levels correspond with a lower °Brix.

There are a multitude of factors that could have contributed to why our study yielded differing results from other, similar research. Fungus appeared to be growing in the compost radishes' environment and after harvesting, signs of a disease called black root rot were present on only the radishes grown in compost, whereas the control radishes seemed to be healthy. Black root rot is caused by the fungus *Thielaviopsis basicola* and can lead to stunted growth of crops and limit nutrient translocation ("Black root rot: The IDM fast facts series." 2016). These are likely causal factors in the negative relationship observed between high soil potassium levels with growth and sugar content in radishes. Fungi are much more likely to grow in compost rather than control soil because, as decomposers, they aid the decomposition process required for composting (Setälä and McLean 2004). This is why the fungus and disease only appeared in the compost radishes. In addition to black root rot, a black fly infestation also occurred during the experiment. Studies show that black fly larvae has a substantial negative effect on plant growth (Alattar et al. 2016). This infestation is yet another factor that could have prevented the compost radishes from becoming healthy. In future studies, to remove these inhibiting factors, adjusting the method of macronutrient delivery would be optimal. Instead of using compost to increase potassium levels, using a Potash fertilizer or directly introducing potassium ions into the soil environment could remove the confounding variables that the compost caused.

Another reason that our results may have differed from other literature findings could be the concept of macronutrient suppression. Çelik et al. found that high levels of soil potassium may decrease the uptake of other essential micro and macronutrients such as P, Mg, and Ca (Çelik et al. 2010). Soil potassium content in compost measured as consistently very high throughout the course of the experiment which likely suppressed the uptake of other nutrients and inhibited plant development, leading to a lower sugar content. In future studies, a moderate potassium level should be aimed for to counteract this effect. More research could also be done to examine the effect of a more balanced nutrient-rich environment on sugar content in radishes.

The results of this study show that possible community interactions should always be accounted for since all living things are members of a community. The presence of just two unexpected species in the compost environment greatly affected the predicted results. In this case, amensalism was observed in both black flies and fungi as the effect of the radishes on the fungi and flies was neutral, however the effect of the effect of the fungi and flies on the radishes was negative. Our hypothesis did not account for possible community interactions that could occur in such a small system. Although plants grown in a greenhouse may seem like they are involved in few species interactions, more studies are beginning to look at plant-plant interactions within greenhouses (Heuvelink and González-Real 2008). Overall, the results of this study show that even in the smallest and seemingly simplest ecosystem, complex community interactions can be taking place.

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