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Article

Which fruit peel helps retain the most soil moisture?

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SUMMARY

Around 42% of fresh water is used for irrigation in the US. Since freshwater availability is limited and the population is increasing, development of innovative methods to help conserve water are critical. The aim of this research project was to study comparative efficacy of various fruit peels in retaining soil moisture. Naturally occurring water absorbent polymers such as pectin are present in fruit peels. We hypothesized that adding fruit peels would help water retention in soil and that orange peels will be the most effective in retaining soil moisture compared to other fruit peels. We tested the ability of orange, banana, and kiwi peels to retain soil moisture. Peels were ground up with olive oil and mixed with soil. Soil moisture levels were recorded using a sensor coded by this author first after adding water and at 24-hour intervals over a 96-hour observation period. This was repeated for five trials. At baseline, the moisture levels were relatively the same, at 24 hours the orange peel retained the most moisture and this result was sustained at 48- hour, 72 -hour, and 96- hour readings. We showed that orange peels retained the most moisture however, banana and kiwi peels also helped lock in more moisture compared to the control.

INTRODUCTION

Irrigation is a crucial factor to consider when deciding on the suitability of land for agriculture. Dry weather and drought are becoming an increasing problem for the world. With increases in food demand to feed a growing population, and water being a limited commodity, methods to optimize water use are critical. In the United States of America (USA), 42% of fresh water is used for agricultural purposes (1). Water needs to be pumped to farms from reservoirs and canals, hence water conservation can also help decrease energy use. Innovations aimed at conserving water and using technological advances to help perfect available resources are a key area of investigation.

In soil, plants soak up nutrients with their roots, such as water, nitrogen, phosphorus, and potassium. Water is constantly being wasted because soil cannot hold on to moisture efficiently. Superabsorbent polymers (SAPs) have been studied due to their ability to soak up and hold moisture up to 300 times their weight through diffusion (2). Polysaccharide bonds distinguish SAPs one from another. When a sodium-based SAP is placed in a high concentration of water, the water tends to spread into the polymer due to diffusion, therefore absorbing water. However, SAPs are not biodegradable and are expensive. SAPs also have dangerous chemicals like acrylic acid and sodium hydroxide that can damage crops (2).

According to previous research, citrus fruits have a high number of natural water-absorbent polymers in their peels, such as pectin (3). Pectin is an acidic hetero polysaccharide (3). Studies on orange peels have shown that they are composed of 64% polysaccharide, out of which 45% is pectin, making them great biodegradable polymers (2). Oranges are widely available, and peels are normally thrown in the trash. Additionally, orange peels that are a waste product of the orange juice industry can be an environmentally efficient alternative to SAPs (4).

Banana peels are made up of a vast amount of nutrients and have many absorbent polymers as well (5). Bananas are cheap and easily accessible all year, around the world. Banana peels can be composted and added as a fertilizer/compost to increase plants' potassium levels. However, not much is known about the water retaining ability of banana peels. Kiwi peels contain pectin methyl esterase inhibitor which catalyzes the de-methyl esterification of pectin, keeping it intact. De-methyl esterification is a chemical process that converts acid into fats. (6,7). Similarly, there is a lack of literature about the use of kiwi peels. In addition, there is no existing literature, to our knowledge, comparing different fruit peels' ability to retain water in soil.

Soil moisture can be measured using gypsum blocks (8). Gypsum blocks measure the difference in the electrical tension in the soil. For measuring soil moisture at home, a simple micro bit measuring device can be used. The micro bit senses soil moisture by a process called analog to digital conversion (ADC). The micro bit converts the voltage of the moisture detected into a digital number. The digital number units are called counts (8) We coded and attached electrodes to our micro bit, that was our moisture sensor.

Fruit peels can be dried to absorb water through diffusion, following the concentration gradient. Water travels from a high concentration gradient, such as previously watered soil, to a low concentration gradient, such as dried fruit peel. Fruit peels can absorb the large amounts of moisture after this process through emulsion polymerization (8). Emulsion polymerization is an emulsion of water, a monomer, and a surfactant. For using fruit peels as water absorbents, oil in water emulsion polymerization is used, where droplets of the monomer are mixed and crushed with water.

We hypothesized that orange peels would be most effective in retaining soil moisture. We compared the effect of orange, kiwi, and banana peels in soil moisture retention by watering the soil then measuring the moisture levels after 5 consecutive 24-hour periods. Our control was plain soil,

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so we were able to compare the moisture retention abilities of each peel accurately. Orange peels proved to be the most effective when it came to moisture retention. Kiwi and banana peels also proved to help keep soil moisture levels up compared to regular soil, but orange peels worked the best. Moving forward, these results along with the soil moisture sensor can be helpful in the farming industry. Due to drought rates increasing, local farmers need a cost-efficient way to save water.

RESULTS

We assessed the impact of different fruit peels on the retention of soil moisture by making a moisture sensor and recording the results over five consecutive 24-hour periods after watering the soil. Various fruit peels evaluated showed efficacy in keeping soil moisture. The average moisture count of the three types of fruit peels and the control were in the range of 1000-1015 counts at time zero **(Table 1)**. At 96 hours, the soil moisture retention count was 755.4, 714.6, 711.2, and 656.4, for orange, kiwi, banana, and control respectively. The calculated percentage decline in moisture throughout the 96 hour observation period was 25.6%, 29.6%, 29.8%, and 34.5%, for orange, kiwi, banana, and control respectively **(Figures 1 and 2)**.

Amongst the three fruit peels tested, ground orange peels kept the most moisture when compared to the ground peels of kiwi, banana, and the control (no peel) **(Table 1)**. Results indicate adding fruit peels to soil helps with water retention and orange peels kept the most moisture in soil because of the higher amounts of polymers. Throughout the 96-hour observation period orange peels were noted to be the most efficient in keeping soil moisture. These results were shown to be statistically significant by running a One-Way ANOVA test **(Table 2)**.

Moisture Reading	Immediately after water added	24 hours	48 hours	72 hours	96 hours	Percent decline[a]
Orange peel	1014.8	990.8	864	784.8	755.4	25.6%
Kiwi peel	1015.4	980.8	845	745	714.6	29.6%
Banana peel	1013.6	979.2	832.2	744.6	711.2	29.8%
Control	1001.4	963.6	806.6	712.8	656.4	34.5%

Table 1: Average soil moisture levels. Average measurements of soil conductivity throughout all 5 trials by the micro bit sensor, and the percent decline of all fruit peel and control samples during the 96-hour observation period.
[a]Percent decline was taken by subtracting the measurement taken at 96 hours from the measurement immediately after the water was added and dividing by the measurement immediately after the water was added.

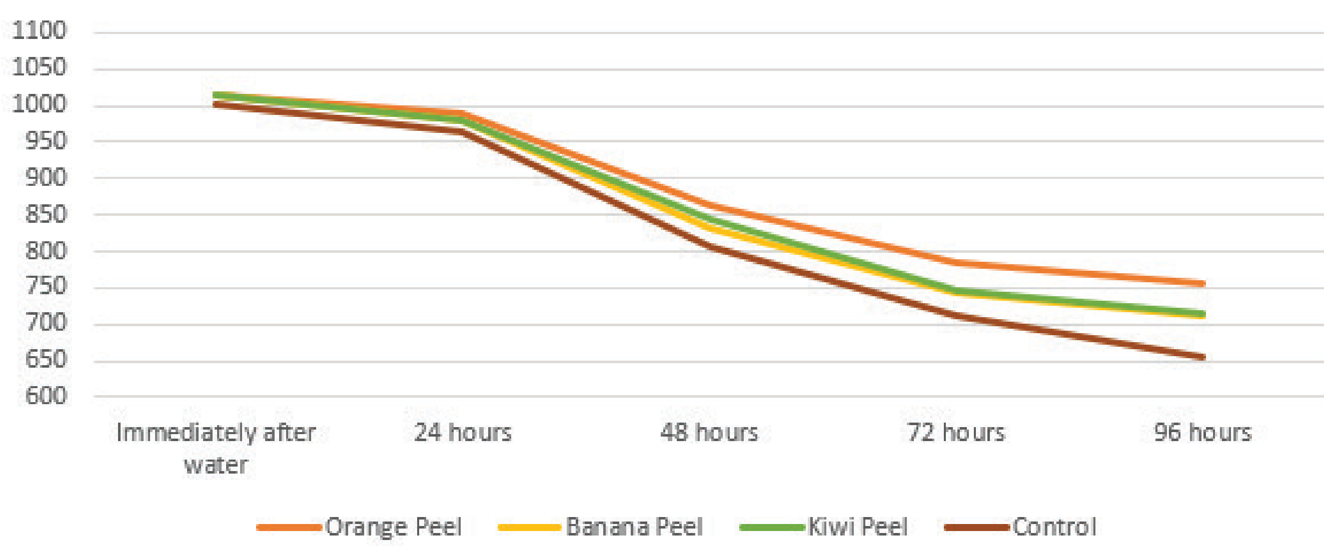

Figure 1: Change in moisture levels over time. Moisture level fluctuation over time. Orange peel kept the most moisture at the 96-hour mark.

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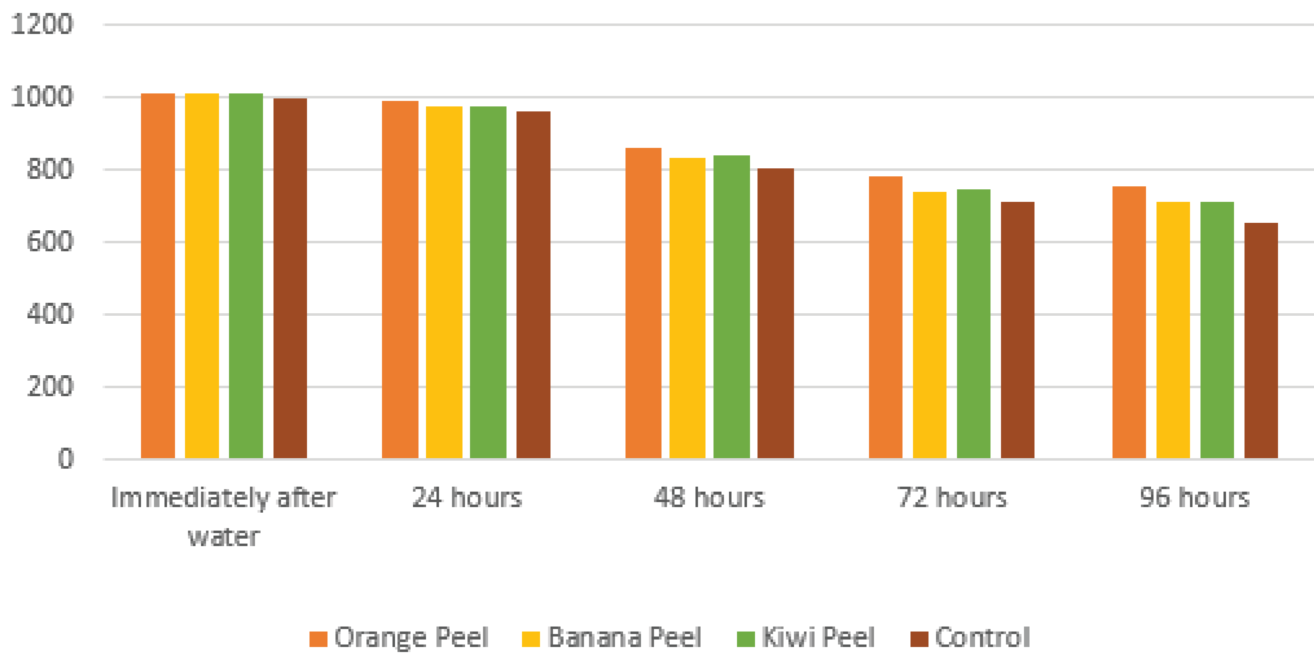

Figure 2: Change in moisture levels over time. Soil moisture retention over time.

Pairs	Mean Difference	95% Confidence Interval	*p*-value
Control-Banana	-54.8	[-58.96, -50.64]	<0.0001
Kiwi-Banana	3.4	[-0.76, 7.56]	0.1301
Orange-Banana	44.2	[40.04, 48.36]	<0.0001
Kiwi-Control	58.2	[54.04, 62.36]	<0.0001
Orange-Control	99.0	[94.84, 103.16]	<0.0001
Orange-Kiwi	40.8	[36.64, 44.96]	<0.0001

Table 2: One-Way ANOVA test performed on the results of this experiment.

DISCUSSION

Only about 3% of water is available as fresh water on Earth. Water is such a critical resource; many experts and agencies feel that future wars will be over water. Periodic droughts have been more common in recent years (9). Almost 57% of the continental USA is currently facing drought. It is therefore critical to raise awareness about water conservation and develop sustainable innovations to conserve water (9). Since irrigation uses roughly 42% of water, technological solutions directed at perfecting water use will help decrease water usage and may additionally help decrease energy use needed to pump water to farmlands (9). Optimizing irrigation may also improve crop yield.

Our study indicates that fruit peels can help in soil water retention and among the fruit peels used for this study orange peels retained more moisture in comparison to kiwi and banana fruit peels. The results of ANOVA further highlight a significant relationship between the type of fruit peel and the amount of water retained in soil as measured by the micro sensor coded by this author where the voltage of the soil moisture detected is converted to a digital number. One of the most important mechanisms implicated in the retention of soil moisture by dried fruit peels is the presence of a high number of natural water-absorbent polymers, such as pectin.

One of the key limitations of our study was that the method for measuring soil moisture, although innovative, had its limitations in not being as sturdy and accurate as a commercially purchased soil moisture sensor. It also makes it difficult to carry out this study in field settings on a large scale. Additionally, the process of boiling, drying, and grinding the peels and mixing with oil makes the process tedious and would be challenging to apply on a large scale.

Our study builds on earlier projects which suggested that fruit peels are able to conserve soil moisture (3). Repurposing fruit peels in this manner can minimize accumulation of kitchen waste in landfills, in turn decreasing greenhouse gas emissions. It also replenishes the soil with nutrients. Barnossi et al., discuss the proper use of fruit peels including peels of tangerines, pomegranate and banana and their specific uses in animal feed, soil fertilization, specific compost production and bio-adsorbents (10). In fact, they also emphasize the valorization of fruit peels for manufacturing products such as enzymes and essential oils for use in the medical and cosmetic industry. Although they discuss the importance of conserving natural resources, such as, soil, water, and air, none of the studies mentioned in the review specifically address the water retention in soil because of the addition of fruit peels.

This pilot data can inspire further investigation, perhaps in an industry funded laboratory setting with equipment and expertise, with more variable such as testing different doses of the peel extracts on plant growth and by evaluating their effect on plant height which would also help explore the nutritional value of the fruit peels and not just their water retention potential. This investigator is exploring on further

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tweaking the home coded moisture sensor to make it more sophisticated so as to have the option of signaling the farm owner when the sensor shows low moisture in soil, such as a mobile phone application so that water sprinkler may be turned on remotely.

MATERIALS AND METHODS

Fruit peels (orange, kiwi, banana) were boiled in water separately, strained, dried, and ground up in kitchen grinder after mixing with a few drops of olive oil. Two cups of topsoil were placed in four different equally sized containers and peels were added to topsoil and mixed (only one type of peel was added to each pot). 60 mL of water was added to each of the three pots and the soil moisture sensor, which was coded using JAVA script by this student author, was used to measure conductivity as a measure of moisture **(Figure S1)**. Immediately after adding water, sequential measurements were done at 24-hour intervals for a total of 96 hours. The results for each condition were tabulated, averaged, and compared using Microsoft Excel. One-Way ANOVA was performed for further analysis. The average level of the soil moisture over 5 trials is noted in **Table 1** and the readings of each of the 5 trials in found in the appendix as **Tables S1-S5**.

The gravimetric method was used to compare soil moisture readings as measured by the sensor (coded by this author using JAVA script which gives measurements in digital counts this was the laboratory recommended method to standardize the accuracy of the soil moisture sensor. Fresh soil was placed in the kitchen oven at 105 °C overnight, and the next morning the soil sample was weighed again. The difference between fresh topsoil weight and dried topsoil divided by weight of first sample of soil gave a measure of soil moisture in grams of H_2O per gram of soil.

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Appendix

Moisture Reading	Immediately after water added	24 hours	48 hours	72 hours	96 hours
Orange peel	1012	987	862	788	757
Kiwi peel	1019	988	849	748	717
Banana peel	1007	987	828	743	710
Control	994	964	802	716	655

Table S1. Data from Trial 1. This displays the data collected from the first trial.

Moisture Reading	Immediately after water added	24 hours	48 hours	72 hours	96 hours
Orange peel	1015	992	863	786	755
Kiwi peel	1020	984	844	748	711
Banana peel	1008	982	835	743	713
Control	993	967	810	716	656

Table S2. Data from Trial 2. This displays the data collected from the second trial.

Moisture Reading	Immediately after water added	24 hours	48 hours	72 hours	96 hours
Orange peel	1016	992	863	783	758
Kiwi peel	1010	976	842	741	718
Banana peel	1021	974	830	742	709
Control	1009	961	807	711	659

Table S3. Data from Trial 3. This displays the data collected from the third trial.

Moisture Reading	Immediately after water added	24 hours	48 hours	72 hours	96 hours
Orange peel	1017	993	867	785	754
Kiwi peel	1015	979	846	745	712
Banana peel	1016	975	832	744	710
Control	1007	960	803	713	657

Table S4. Data from Trial 4. This displays the data collected from the fourth trial.

Moisture Reading	Immediately after water added	24 hours	48 hours	72 hours	96 hours
Orange peel	1014	990	865	782	753
Kiwi peel	1013	977	845	748	715
Banana peel	1017	978	836	749	714
Control	1004	966	811	709	655

Table S5. Data from Trial 5. This displays the data collected from the fifth and final trial.

```javascript
let moisture = 0
input.onButtonPressed(Button.A, function () {
    basic.showNumber(pins.analogReadPin(AnalogPin.P1))
})
basic.forever(function () {
    moisture = pins.analogReadPin(AnalogPin.P1)
    if (moisture > 1000) {
        basic.showIcon(IconNames.Sword)
    } else if (moisture > 900) {
        basic.showIcon(IconNames.Happy)
    } else {
        basic.showIcon(IconNames.Sad)
    }
})
```

Figure S1. Code written in Java script.