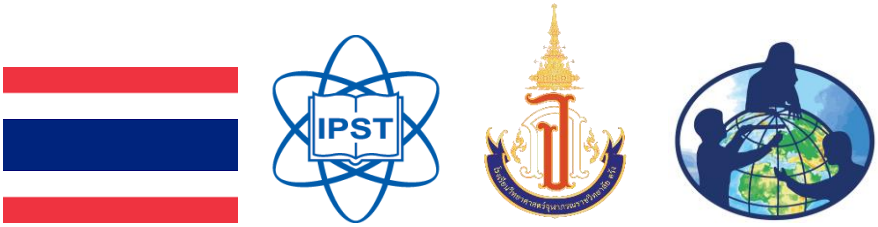

Study of the Impacts of Soil Amendment Materials on Soil Quality and Plant Growth

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Abstract

This study aims to create soil amendment materials from natural waste materials, test the water absorption of these soil amendment materials, and examine soil quality before and after planting, as well as plant growth. Four different soil amendment formulas were developed using various ingredients, including peanut shells, watermelon peels, sugarcane bagasse, and goat droppings. The water absorption capacity of all four formulas was tested, and it was found that Formula 3 had the highest percentage of water absorption.

Regarding soil quality before and after planting choy sum, the results showed that Formula 3 had the highest soil moisture percentage. The pH of the soil increased after planting in all formulas. The mineral content analysis revealed that Formula 1 and Formula 2 showed an increase in nitrogen, phosphorus, and potassium. Formula 3 had an increase in phosphorus and potassium. Formula 4 had an increase in nitrogen and phosphorus. The control group showed no increase in mineral content. As for the growth rate of choy sum over four weeks, Formula 1 resulted in the best plant growth. This is likely due to the high amount of peanut shells in Formula 1, which serve as a significant source of nitrogen for plants.

Keywords: Soil Amendment Materials , Soil Quality , Plant Growth

Introduction

Environmental problems resulting from global warming and pollution are critical issues that the world must address, particularly concerns related to soil dryness and mineral depletion. These challenges require increased global efforts to prevent soil degradation and ensure its continued suitability for agriculture, which is a fundamental aspect of human life. The use of chemical fertilizers and other synthetic solutions to replenish soil nutrients may have adverse effects, including long-term soil degradation and the accumulation of harmful chemicals in agricultural products. This, in turn, poses potential health risks to consumers. Additionally, global warming continues to intensify, leading to an exponential increase in water consumption to combat soil dryness. This growing demand for water could contribute to resource shortages in the future. Currently, a significant portion of agricultural products is used for human consumption, but many byproducts, such as fruit peels, remain unused and become waste. If these organic materials are discarded in landfills and decompose under anaerobic conditions, they generate greenhouse gases, particularly methane. Methane has a global warming potential 25 times greater than carbon dioxide, making it a significant contributor to climate change. Studies have shown that certain fruit peels, such as peanut shells, watermelon peels, and bagasse, have excellent water-absorption properties and contain essential minerals beneficial to plant growth. These properties align with efforts to address soil degradation.

To enhance the value of these natural waste materials and reduce overall waste generation, this study explores their potential use in creating soil amendment materials. These materials aim to improve soil moisture retention and enhance mineral content, offering a sustainable alternative to chemical fertilizers. By doing so, they help mitigate soil dryness and nutrient depletion while reducing the reliance on water resources for soil maintenance. This initiative represents an innovative and eco-friendly approach to promoting sustainable agriculture.

Research Questions:

1.Can soil amendment materials which made from natural waste materials maintain soil moisture?

2.Can soil amendment materials which made from natural waste materials increase minerals in the soil?

3.Do soil amendment materials which made from natural waste materials affect plant growth?

Objectives:

1.Soil Amendment materials which made from natural waste materials can maintain soil moisture.

2.Soil Amendment materials which made from natural waste materials can increase minerals in the soil.

3.Soil Amendment materials which made from natural waste affect plant growth.

Materials:

1.Peanut Shells	7.Pots
2.Watermelon Peels	8.Potting Soil
3.Sugarcane Bagasses	9.Fertilizer Pellet Machine
4.Goat droppings	10.Guangdong Seeds
5.Shaker	11.NPK Testers
6.Hot Air Dryer	12.Moisture and pH meter

Methods:

1. Create soil amendment materials from natural waste materials

1.1 Take three types of natural waste materials, peanut shells, watermelon peels, and sugarcane bagasse, and wash them thoroughly. Cut into small pieces. Dry in the sun then put them in a hot air dryer at 80 celsius for 48 hours and grind them into a fine powder.

1.2 Put peanut shell powder, watermelon peel powder, and surgarcane bagasse powder into a fertilizer pellet machine with a diameter of 4 millimeters and a length of 13 millimeters, As the soil amendment materials are divided into 4 formulas as follows,

Formula 1 : include peanut shells for 20% , watermelon peels for 10% , sugarcane bagasses for 10% and goat droppings for 60% (Percentage by mass)

Formula 2 : include peanut shells for 10% , watermelon peels for 20% , sugarcane bagasses for 10% and goat droppings for 60% (Percentage by mass)

Formula 3 : include peanut shells for 10% , watermelon peels for 10% , sugarcane bagasses for 20% and goat droppings for 60% (Percentage by mass)

Formula 4 : Goat droppings for 100% (Percentage by mass)

2.Test the water absorption of soil amendment materials

Take all 4 formulas of soil amendment materials, 20 grams per formula soak in 100 mL water for 1 hour, when the time is up, pour out the remaining water. then weigh the samples were then placed in a hot air dryer at 110 degrees Celsius for 24 hours, then weighed and calculate the water absorption value using the equation:

% Water absorption = $\frac{(Ww-Wd)}{Wd} \times 100$

Ww = Weight of soil amendment material before soaking water (g)

Wd = Weight of soil amendment material material after placed in hot air dryer (g)

3.Soil and experimental set preparing

3.1 Measure soil quality according to the GLOBE method by measuring moisture,pH, and nutrients in the soil.The soil sample collection point was determined in the area of Princess Chulabhorn Science High School Trang (latitude 7.5544954, longitude 99.5567734), collect soil samples, The collecting area was designated as 100x50 meters and soil samples were collected from the soil surface down to a depth of 10 centimeters. The soil was mixed before sampling 600 grams of soil and baked at 105 degrees Celsius for 24 hours, Then consider about moisture, soil texture, measure pH , Nitrogen , Phosphorus , Potassium using pH and NPK testers, and send data into GLOBE Data Entry.

3.2 Prepare 5 experimental sets, 5 pots per set. Add soil from 1) into the pots, 800 grams per pot. Add 200 grams of soil amendment formulas 1-4, respectively. Experimental set 5 (Formula 5) is a control experiment.

4.Study of plant growth and soil quality after planting

4.1 Plant choy sum seedlings that are 2 weeks old into all 5 experimental sets. Water 500 ml., measure soil moisture every day at 6:00 a.m. and 6:00 p.m., and water the next time 500 ml when it is found that the moisture has dropped to 50%. The growth of the guangdong was collected every week for 4 weeks. After 1 week, 1 choy sum plant was removed from each pot to measure its growth until 4 weeks had passed. By measuring the height of the plant (a), the width of the leaves (b), the length of the leaves (c), and the number of leaves (d), as shown in the 1st picture.

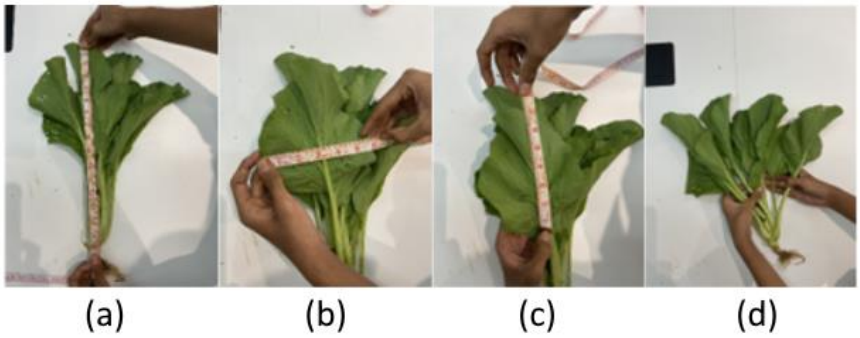


Figure 1: shows the measurement of plant height (a), leaf width (b), and leaf length (c) and number of leaves (d).

4.2 Measure soil quality after planting choy sum in every experimental set according to the GLOBE method by putting the soil into hot air dryer at 105 celsius for 24 hours, then measuring the moisture, pH, and nutrients in the soil by measuring the pH with a pH meter and studying the mineral nutrients, including nitrogen, phosphorus, and potassium, of the soil with an NPK test, then send data into GLOBE Data Entry.

5.Data Analysing

5.1 Water absorption analysis Soil quality and plant growth using the arithmetic mean and standard deviation.

5.2 Compare soil quality and plant growth using One Way ANOVA

Result

1.Studying of water absorption of soil amendment materials.

A study of the water absorption of soil amendment materials found that soil amendment material formula 3 had the highest percentage of water absorption. Followed by Formula 2, Formula 4, and Formula 1, respectively, as shown in the 2nd picture

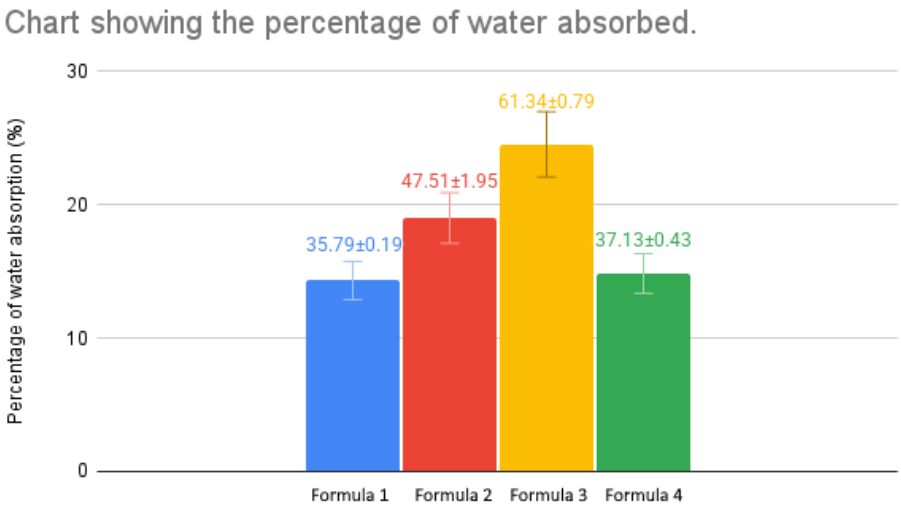


Figure 2: shows the percentage of water absorbation of soil amendment materials

2.Studying of soil quality before and after plating

2.1) A study of soil moisture before and after planting found that the percentage of soil moisture of the soil amendment materials was significantly different at .05, with formula 3 of soil amendment having the best soil moisture percentage, followed by formula 2, formula 1, formula 4, and formula 5, respectively, as shown in the 3rd picture

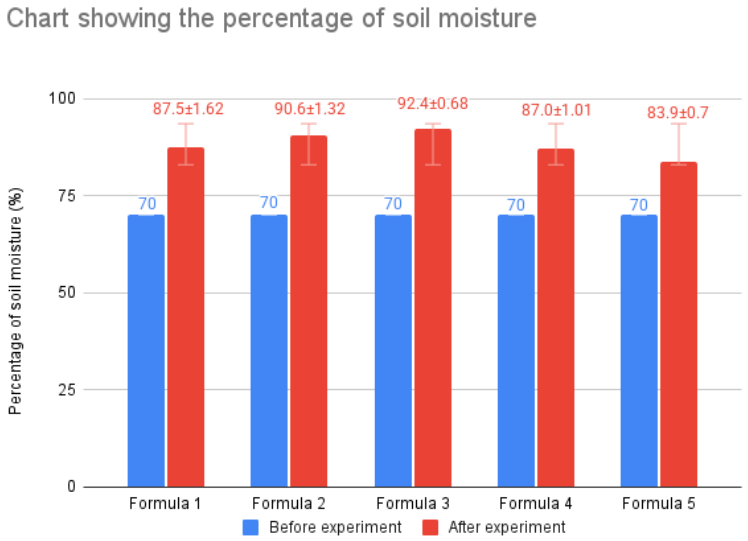


Figure 3: shows the percentage of soil moisture

2.2) Studying the pH of the soil before and after planting. The results of the study found that the pH of the soil after planting choy sum was higher than before planting in all formulas, as shown in the 4th picture

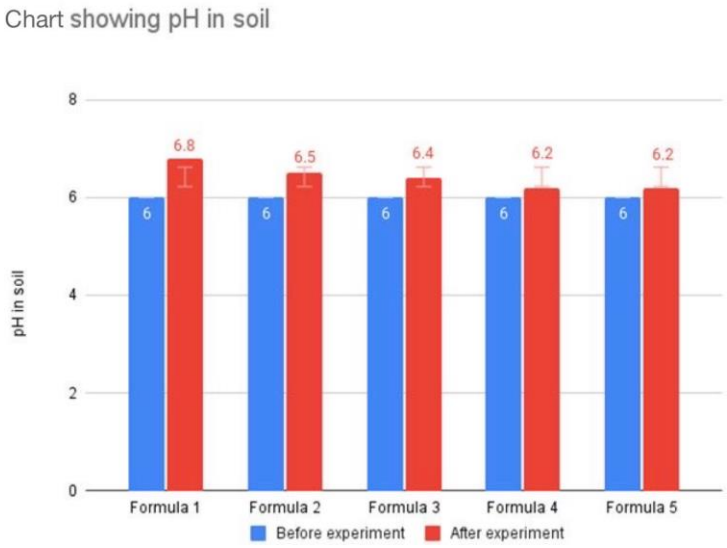
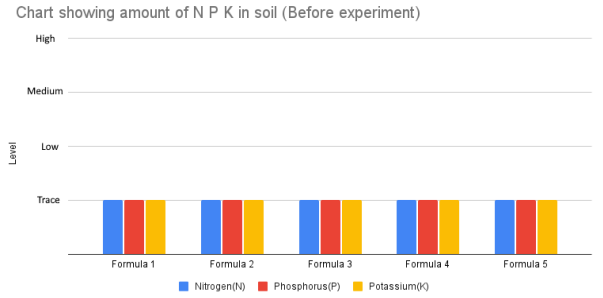


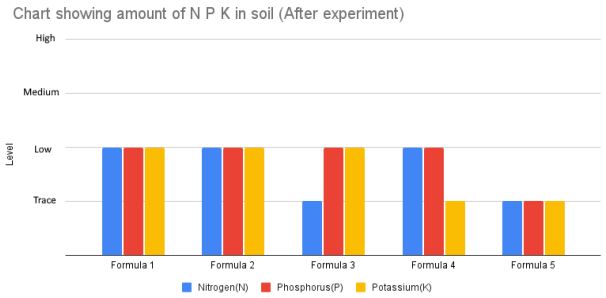
Figure 4: shows the pH in soil

2.3) A study of the amount of minerals in the soil found that the amount of minerals in the soil after planting crops using soil amendments material Formula 1 and Formula 2 had increased amounts of nitrogen, potassium and phosphorus and Formula 3 had increased phosphorus and

potassium. and soil amendment material formula 4 has increased nitrogen and phosphorus, As for Formula 5 (control), there was no increase in minerals in the soil, as shown in the 5th picture.



(a)



(b)

Figure 5: shows the minerals in soil before (a) and after (b) experiment.

3.Studying of plant growth

3.1) The study of plant height revealed that the growth rates and plant heights differed at the statistical significance level of .05, with Formula 1 having the highest plant height, as shown in the 6th picture.

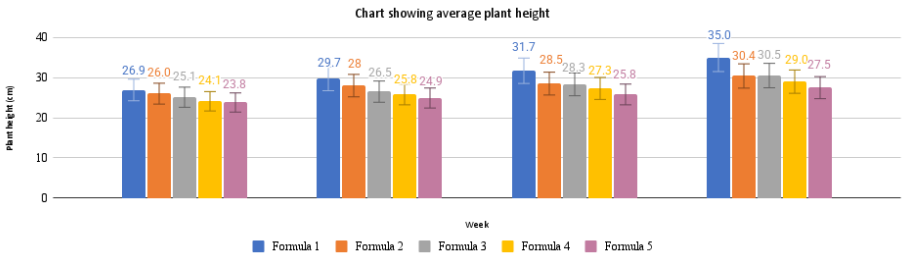


Figure 6: shows the height of choy sum

3.2) The study of plant width revealed that the growth rates of plant leaf widths differed at the statistical significance level of .05, with Formula 1 having the highest width, as shown in the 7th picture.

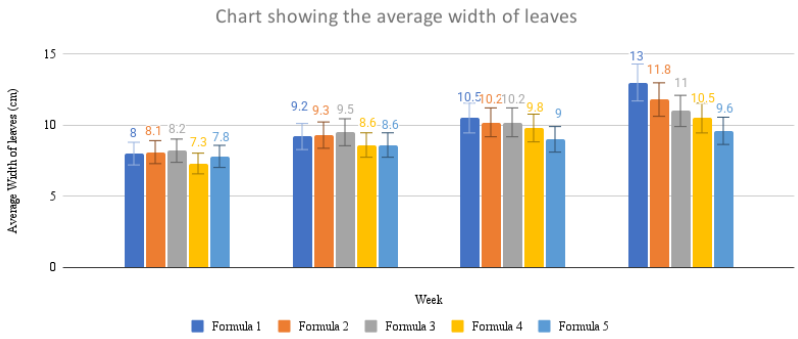


Figure 7: shows the width of choy sum

3.3) The study of the number of leaves found that the average number of additional leaves of the plants differed at the statistical significance level of .05, with Formula 1 having the highest number of leaves, as shown in the 8th picture.

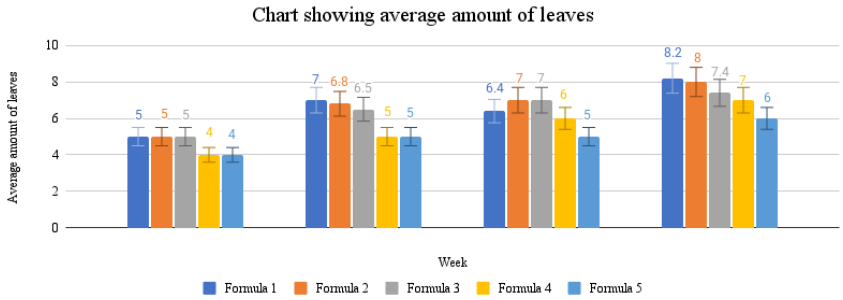


Figure 8: shows the number of leaves of choy sum

Dicussion

From the table it can be seen that soil amendment material formula 3 can absorb water the best and the experimental set that added soil amendment material formula 3 also had the highest soil moisture. However, when considering plant height, leaf width and number of leaves, it can be observed that the experimental set that added soil amendment material formula 1 resulted in plants with the highest plant height, leaf width and number of leaves.

Conclusion

The water absorption test of soil amendment materials and soil moisture values found that formula 3 had the highest percentage of water absorption (61.34±0.79) and the highest percentage of soil moisture (92.4±0.68), which is consistent with the development of water-absorbing materials from sugarcane bagasse for soil moisture retention and increasing water use efficiency in the agricultural sector (Piriyathorn Suwannamala et al., 2020)

The study of soil quality and growth of choy sum found that the pH of the soil after planting was higher than before planting in all formulas. The amount of minerals in the soil after planting showed that formulas 1 and 2 had increased nitrogen, potassium, and phosphorus. Formula 3 had increased phosphorus and potassium. Formula 4 had increased nitrogen and phosphorus. In the control set, there was no increase in minerals in the soil. And the growth of choy sum in 4 weeks showed that formula 1 had the highest average leaf height (35.0 cm), leaf width (13.0 cm), and number (8.2 leaves) because formula 1 contained a large amount of peanut shells, which are an important source of nitrogen for plants. This is consistent with the research on the effects of agricultural waste on the growth of choy sum. It was found that choy sum planted in soil mixed with peanut shells promoted plant growth with the highest average number of leaves and height per plant (Hrutai Thaisukchat et al., 2018).

Acknowledgments

We would like to thank Dr. Anantanit Chumsri from Rajamangala University of Technology Srivijaya, Trang Campus, for her advice and suggestions in the research process.

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We would like to thank Princess Chulabhorn Science High School Trang's director and teacher and parents who support this research

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GLOBE Data Entry

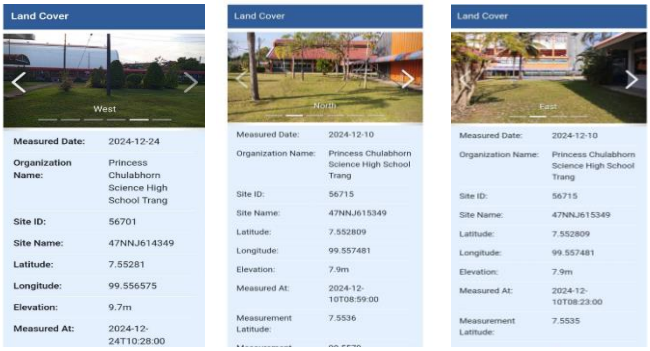

Figure 9: Send land surface information into Land Cover data

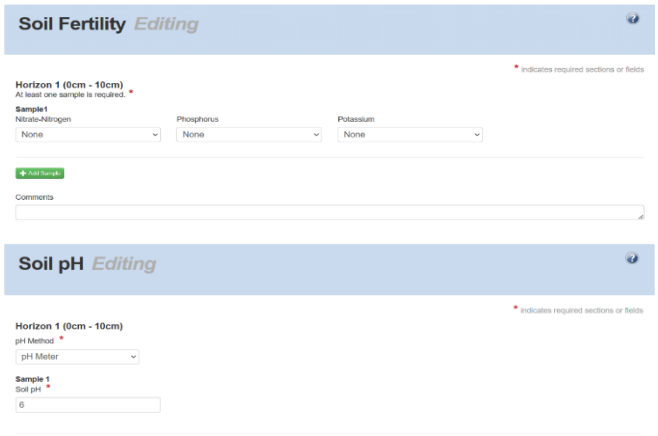

Figure 10: Send soil quality information into data entry

Optional Badge

1. I AM A PROBLEM SOLVER

This research contributes to solving global environmental and sustainability problems. By using natural waste materials to develop them as soil improvement materials. Reduce the amount of organic waste and reduce greenhouse gas emissions caused by the decomposition of waste in anaerobic conditions. It also reduces the use of chemical fertilizers, which are the cause of soil and water pollution. It helps conserve water resources by increasing the ability to retain moisture in the soil. Promote agriculture that is environmentally friendly and in line with the Sustainable Development Goals In the field of effective management of natural resources.

2. I MAKE AN IMPACT

This research creates a positive impact on the environment by reducing the amount of organic waste through the reuse of natural waste materials. Reduce greenhouse gas emissions from the decomposition of organic waste in anaerobic conditions. It also reduces the use of chemical fertilizers that pollute the soil and water sources. Promotes the conservation of water resources through increasing the ability of soil moisture to be stored. It also helps to support sustainable agriculture. Reduce costs for farmers and be in line with the global sustainable environmental development guidelines.

3. I AM A DATA SCIENTIST

We have collected information. Data and statistical analysis Using statistical tools including Arithmetic mean and standard deviation In analyzing the experimental results And we have the ability to explain and present data in charts showing the results of experiments. and speaking in a way that is easily understood

Appendix with raw data

Figure 11: Peanut shell

Figure 12: Watermelon Peels

Figure 13: Sugarcane Bagasses

Figure 14: Goat droppings

Figure 15: Formula 1

Figure 16: Formula 2

Figure 17: Formula 3

Figure 18: Formula 4

Figure 19: Prepare experimental set for 5 sets, 5 pots per set

Figure 20: Plant choy sum tree into every pot

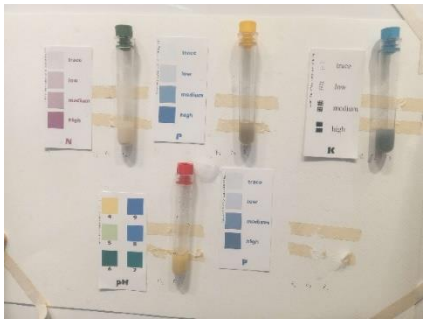

Figure 21: Test soil quality according to GLOBE methods

Date	Watering	Formula 1						
		Pot 1	Pot 2	Pot 3	Pot 4	Pot 5	Average	s.d.
4/1/68 6:00AM	First	4	4	4	4	4	4	0
4/1/68 6:00PM	-	10	10	10	10	10	10	0
5/1/68 6:00AM	-	10	10	10	10	10	10	0
5/1/68 6:00PM	-	10	10	10	10	10	10	0
6/1/68 6:00AM	-	10	10	10	10	10	10	0
6/1/68 6:00PM	-	10	10	10	10	10	10	0
7/1/68 6:00AM	-	9	10	9	8	10	9.2	0.74833148
7/1/68 6:00PM	-	8	10	8	8	9	8.6	0.8
8/1/68 6:00AM	-	6	8	7	6	8	7	0.89442719
8/1/68 6:00PM	Second	4	6	5	4	7	5.2	1.16619038
9/1/68 6:00AM	-	10	10	10	10	10	10	0
9/1/68 6:00PM	-	10	10	10	10	10	10	0
10/1/68 6:00AM	-	10	10	10	10	10	10	0
10/1/68 6:00PM	-	10	10	10	10	10	10	0
11/1/68 6:00AM	-	10	10	10	10	10	10	0
11/1/68 6:00PM	-	10	10	10	10	10	10	0
12/1/68 6:00AM	-	9	10	10	10	10	9.8	0.4
12/1/68 6:00PM	-	8	9	10	8	10	9	0.89442719
13/1/68 6:00AM	-	8	9	10	7	10	8.8	1.16619038
13/1/68 6:00PM	Third	7	7	7	7	8	7.2	0.4
14/1/68 6:00AM	-	10	10	10	10	10	10	0
14/1/68 6:00PM	-	10	10	10	10	10	10	0
15/1/68 6:00AM	-	10	10	10	10	10	10	0
15/1/68 6:00PM	-	9	9	10	10	10	9.6	0.48989795
16/1/68 6:00AM	-	9	8	9	9	10	9	0.63245553
16/1/68 6:00PM	-	8	8	8	9	9	8.4	0.48989795
17/1/68 6:00AM	-	8	8	7	8	9	8	0.63245553
17/1/68 6:00PM	-	7	8	7	6	8	7.2	0.74833148
18/1/68 6:00AM	-	7	7	7	6	8	7	0.63245553
18/1/68 6:00PM	Fourth	6	7	7	6	7	6.6	0.48989795
19/1/68 6:00AM	-	10	10	10	10	10	10	0
19/1/68 6:00PM	-	10	10	10	10	10	10	0
20/1/68 6:00AM	-	10	10	10	10	10	10	0
20/1/68 6:00PM	-	10	10	10	9	10	9.8	0.4
21/1/68 6:00AM	-	9	10	10	9	10	9.6	0.48989795
21/1/68 6:00PM	-	9	9	10	8	9	9	0.63245553
22/1/68 6:00AM	-	9	8	9	8	9	8.6	0.48989795
22/1/68 6:00PM	-	8	7	8	7	9	7.8	0.74833148
23/1/68 6:00AM	-	7	7	7	6	8	7	0.63245553
23/1/68 6:00PM	Fifth	6	7	7	6	7	6.6	0.48989795
24/1/68 6:00AM	-	10	10	10	10	10	10	0
24/1/68 6:00PM	-	10	10	10	10	10	10	0
25/1/68 6:00AM	-	10	10	10	10	10	10	0
25/1/68 6:00PM	-	9	10	10	10	9	9.6	0.48989795
26/1/68 6:00AM	-	9	9	10	10	9	9.4	0.48989795
26/1/68 6:00PM	-	8	9	9	10	8	8.8	0.74833148
27/1/68 6:00AM	-	7	8	8	9	8	8	0.63245553
27/1/68 6:00PM	-	7	7	8	8	8	7.6	0.48989795
28/1/68 6:00AM	-	7	6	7	7	7	6.8	0.4
28/1/68 6:00PM	Sixth	7	6	7	6	6	6.4	0.48989795
29/1/68 6:00AM	-	10	10	10	10	10	10	0
29/1/68 6:00PM	-	10	10	10	10	10	10	0
30/1/68 6:00AM	-	10	10	10	10	10	10	0
30/1/68 6:00PM	-	10	10	10	10	10	10	0
31/1/68 6:00AM	-	9	10	9	9	10	9.4	0.48989795
31/1/68 6:00PM	-	8	9	7	8	9	8.2	0.74833148
1/2/68 6:00AM	-	8	8	7	7	8	7.6	0.48989795
1/2/68 6:00PM	-	8	8	6	7	7	7.2	0.74833148
2/2/68 6:00AM	-	7	7	6	7	6	6.6	0.48989795
2/2/68 6:00PM	-	7	7	6	6	6	6.4	0.48989795
Average		8.6	8.83333333	8.76666667	8.55	9	8.75	0.16261748

Figure 22: Soil moisture measuring result (Formula 1)

Date	Watering	Formula 2						
		Pot 1	Pot 2	Pot 3	Pot 4	Pot 5	Average	S.D.
4/1/68 6:00AM	First	4	4	4	4	4	4	0
4/1/68 6:00PM	-	10	10	10	10	10	10	0
5/1/68 6:00AM	-	10	10	10	10	10	10	0
5/1/68 6:00PM	-	10	10	10	10	10	10	0
6/1/68 6:00AM	-	10	10	10	10	10	10	0
6/1/68 6:00PM	-	10	10	10	10	10	10	0
7/1/68 6:00AM	-	8	10	9	10	10	9.4	0.8
7/1/68 6:00PM	-	7	10	9	10	10	9.2	1.16619038
8/1/68 6:00AM	-	6	8	5	5	9	6.6	1.62480768
8/1/68 6:00PM	Second	6	7	4	3	7	5.4	1.62480768
9/1/68 6:00AM	-	10	10	10	10	10	10	0
9/1/68 6:00PM	-	10	10	10	10	10	10	0
10/1/68 6:00AM	-	10	10	10	10	10	10	0
10/1/68 6:00PM	-	10	10	10	10	10	10	0
11/1/68 6:00AM	-	10	10	10	10	10	10	0
11/1/68 6:00PM	-	10	10	10	10	10	10	0
12/1/68 6:00AM	-	10	10	10	10	10	10	0
12/1/68 6:00PM	-	10	10	10	8	10	9.6	0.8
13/1/68 6:00AM	-	8	9	10	10	9	9.2	0.74833148
13/1/68 6:00PM	Third	5	7	8	8	9	7.4	1.356466
14/1/68 6:00AM	-	10	10	10	10	10	10	0
14/1/68 6:00PM	-	10	10	10	10	10	10	0
15/1/68 6:00AM	-	10	10	10	10	10	10	0
15/1/68 6:00PM	-	10	10	10	10	10	10	0
16/1/68 6:00AM	-	10	9	10	10	10	9.8	0.4
16/1/68 6:00PM	-	9	9	10	9	10	9.4	0.48989795
17/1/68 6:00AM	-	8	9	10	9	9	9	0.63245553
17/1/68 6:00PM	-	8	9	9	8	9	8.6	0.48989795
18/1/68 6:00AM	-	7	8	9	7	8	7.8	0.74833148
18/1/68 6:00PM	Fourth	7	7	8	6	7	7	0.63245553
19/1/68 6:00AM	-	10	10	10	10	10	10	0
19/1/68 6:00PM	-	10	10	10	10	10	10	0
20/1/68 6:00AM	-	10	10	10	10	10	10	0
20/1/68 6:00PM	-	10	10	10	10	10	10	0
21/1/68 6:00AM	-	9	10	10	9	10	9.6	0.48989795
21/1/68 6:00PM	-	9	10	10	9	9	9.4	0.48989795
22/1/68 6:00AM	-	8	9	9	9	9	8.8	0.4
22/1/68 6:00PM	-	8	9	9	8	8	8.4	0.48989795
23/1/68 6:00AM	-	7	8	8	8	8	7.8	0.4
23/1/68 6:00PM	Fifth	6	7	7	7	7	6.8	0.4
24/1/68 6:00AM	-	10	10	10	10	10	10	0
24/1/68 6:00PM	-	10	10	10	10	10	10	0
25/1/68 6:00AM	-	10	10	10	10	10	10	0
25/1/68 6:00PM	-	10	10	10	10	10	10	0
26/1/68 6:00AM	-	10	9	10	10	9	9.6	0.48989795
26/1/68 6:00PM	-	10	9	9	10	9	9.4	0.48989795
27/1/68 6:00AM	-	9	9	9	10	8	9	0.63245553
27/1/68 6:00PM	-	9	8	9	9	8	8.6	0.48989795
28/1/68 6:00AM	-	8	7	8	8	7	7.6	0.48989795
28/1/68 6:00PM	Sixth	7	6	7	8	6	6.8	0.74833148
29/1/68 6:00AM	-	10	10	10	10	10	10	0
29/1/68 6:00PM	-	10	10	10	10	10	10	0
30/1/68 6:00AM	-	10	10	10	10	10	10	0
30/1/68 6:00PM	-	10	10	10	10	10	10	0
31/1/68 6:00AM	-	9	10	9	10	10	9.6	0.48989795
31/1/68 6:00PM	-	9	9	9	9	10	9.2	0.4
1/2/68 6:00AM	-	8	8	9	8	9	8.4	0.48989795
1/2/68 6:00PM	-	7	8	8	8	8	7.8	0.4
2/2/68 6:00AM	-	7	7	8	7	8	7.4	0.48989795
2/2/68 6:00PM	-	6	7	7	7	7	6.8	0.4
Average		8.81666667	9.1	9.16666667	9.01666667	9.18333333	9.06666667	0.1336831

Figure 23: Soil moisture measuring result (Formula 2)

Date	Watering	Formula 3						
		Pot 1	Pot 2	Pot 3	Pot 4	Pot 5	Average	S.D.
4/1/68 6:00AM	First	4	4	4	4	4	4	0
4/1/68 6:00PM	-	10	10	10	10	10	10	0
5/1/68 6:00AM	-	10	10	10	10	10	10	0
5/1/68 6:00PM	-	10	10	10	10	10	10	0
6/1/68 6:00AM	-	10	10	10	10	10	10	0
6/1/68 6:00PM	-	10	10	10	10	10	10	0
7/1/68 6:00AM	-	10	10	9	10	9	9.6	0.48989795
7/1/68 6:00PM	-	10	9	9	9	9	9.2	0.4
8/1/68 6:00AM	-	7	7	6	8	9	7.4	1.0198039
8/1/68 6:00PM	Second	4	6	6	8	9	6.6	1.74355958
9/1/68 6:00AM	-	10	10	10	10	10	10	0
9/1/68 6:00PM	-	10	10	10	10	10	10	0
10/1/68 6:00AM	-	10	10	10	10	10	10	0
10/1/68 6:00PM	-	10	10	10	10	10	10	0
11/1/68 6:00AM	-	10	10	10	10	10	10	0
11/1/68 6:00PM	-	10	10	10	10	10	10	0
12/1/68 6:00AM	-	10	10	10	10	10	10	0
12/1/68 6:00PM	-	10	10	10	10	10	10	0
13/1/68 6:00AM	-	8	8	10	10	10	9.2	0.9797959
13/1/68 6:00PM	Third	7	8	8	8	10	8.2	0.9797959
14/1/68 6:00AM	-	10	10	10	10	10	10	0
14/1/68 6:00PM	-	10	10	10	10	10	10	0
15/1/68 6:00AM	-	10	10	10	10	10	10	0
15/1/68 6:00PM	-	10	10	10	10	10	10	0
16/1/68 6:00AM	-	10	9	10	9	10	9.6	0.4
16/1/68 6:00PM	-	10	9	10	9	10	9.6	0.48989795
17/1/68 6:00AM	-	10	9	9	9	9	9.2	0.4
17/1/68 6:00PM	-	9	8	9	9	9	8.8	0.4
18/1/68 6:00AM	-	9	8	9	8	8	8.4	0.48989795
18/1/68 6:00PM	Fourth	8	7	8	7	7	7.4	0.48989795
19/1/68 6:00AM	-	10	10	10	10	10	10	0
19/1/68 6:00PM	-	10	10	10	10	10	10	0
20/1/68 6:00AM	-	10	10	10	10	10	10	0
20/1/68 6:00PM	-	10	10	10	10	10	10	0
21/1/68 6:00AM	-	10	10	10	9	10	9.8	0.4
21/1/68 6:00PM	-	9	10	10	9	10	9.6	0.48989795
22/1/68 6:00AM	-	9	9	9	9	10	9.2	0.4
22/1/68 6:00PM	-	9	9	9	8	9	8.8	0.4
23/1/68 6:00AM	-	8	9	8	8	8	8.2	0.4
23/1/68 6:00PM	Fifth	7	8	8	7	7	7.4	0.48989795
24/1/68 6:00AM	-	10	10	10	10	10	10	0
24/1/68 6:00PM	-	10	10	10	10	10	10	0
25/1/68 6:00AM	-	10	10	10	10	10	10	0
25/1/68 6:00PM	-	10	10	10	10	10	10	0
26/1/68 6:00AM	-	10	10	10	10	9	9.8	0.4
26/1/68 6:00PM	-	10	9	10	9	9	9.6	0.48989795
27/1/68 6:00AM	-	10	9	9	10	8	9.2	0.74833148
27/1/68 6:00PM	-	9	9	9	8	8	8.6	0.48989795
28/1/68 6:00AM	-	8	8	8	8	8	8	0
28/1/68 6:00PM	Sixth	7	7	8	7	7	7.2	0.4
29/1/68 6:00AM	-	10	10	10	10	10	10	0
29/1/68 6:00PM	-	10	10	10	10	10	10	0
30/1/68 6:00AM	-	10	10	10	10	10	10	0
30/1/68 6:00PM	-	10	10	10	10	10	10	0
31/1/68 6:00AM	-	10	9	10	10	10	9.8	0.4
31/1/68 6:00PM	-	9	9	9	10	10	9.4	0.48989795
1/2/68 6:00AM	-	8	9	9	9	9	9	0.63245553
1/2/68 6:00PM	-	8	8	9	8	8	8.4	0.48989795
2/2/68 6:00AM	-	8	7	8	7	8	7.6	0.48989795
2/2/68 6:00PM	-	7	7	7	7	8	7.2	0.4
Average		9.2	9.13333333	9.28333333	9.23333333	9.33333333	9.23666667	0.06863753

Figure 24: Soil moisture measuring result (Formula 3)

Date	Watering	Formula 5						
		Pot 1	Pot 2	Pot 3	Pot 4	Pot 5	Average	S.D.
4/1/68 6:00AM	First	4	4	4	4	4	4	0
4/1/68 6:00PM	-	10	10	10	10	10	10	0
5/1/68 6:00AM	-	10	10	10	10	10	10	0
5/1/68 6:00PM	-	10	10	10	10	10	10	0
6/1/68 6:00AM	-	10	10	10	10	10	10	0
6/1/68 6:00PM	-	10	10	10	10	10	10	0
7/1/68 6:00AM	-	10	10	10	9	9	9.6	0.48989795
7/1/68 6:00PM	-	8	8	10	8	9	8.6	0.8
8/1/68 6:00AM	-	6	6	7	4	5	5.6	1.0198039
8/1/68 6:00PM	Second	5	4	5	3	4	4.2	0.74833148
9/1/68 6:00AM	-	10	10	10	10	10	10	0
9/1/68 6:00PM	-	10	10	10	10	10	10	0
10/1/68 6:00AM	-	10	10	10	10	10	10	0
10/1/68 6:00PM	-	10	10	10	10	10	10	0
11/1/68 6:00AM	-	10	10	10	10	10	10	0
11/1/68 6:00PM	-	9	9	10	10	9	9.4	0.48989795
12/1/68 6:00AM	-	10	9	9	8	9	9	0.63245553
12/1/68 6:00PM	-	8	8	8	8	9	8.2	0.4
13/1/68 6:00AM	-	7	8	6	8	8	7.4	0.8
13/1/68 6:00PM	Third	5	6	6	7	6	6	0.63245553
14/1/68 6:00AM	-	10	10	10	10	10	10	0
14/1/68 6:00PM	-	10	10	10	10	10	10	0
15/1/68 6:00AM	-	10	10	10	10	10	10	0
15/1/68 6:00PM	-	9	9	10	10	9	9.4	0.48989795
16/1/68 6:00AM	-	8	8	8	9	9	8.4	0.48989795
16/1/68 6:00PM	-	8	8	7	8	8	7.8	0.4
17/1/68 6:00AM	-	7	7	7	7	7	7	0
17/1/68 6:00PM	-	7	7	7	6	7	6.8	0.4
18/1/68 6:00AM	-	6	6	6	6	6	6	0
18/1/68 6:00PM	Fourth	5	6	6	6	6	5.8	0.4
19/1/68 6:00AM	-	10	10	10	10	10	10	0
19/1/68 6:00PM	-	10	10	10	10	10	10	0
20/1/68 6:00AM	-	9	10	10	10	9	9.8	0.4
20/1/68 6:00PM	-	9	10	10	9	10	9.6	0.48989795
21/1/68 6:00AM	-	9	9	9	9	9	9	0
21/1/68 6:00PM	-	8	8	9	8	8	8.2	0.4
22/1/68 6:00AM	-	8	8	8	8	7	7.8	0.4
22/1/68 6:00PM	-	7	8	7	7	7	7.2	0.4
23/1/68 6:00AM	-	6	7	6	6	6	6.2	0.4
23/1/68 6:00PM	Fifth	6	7	5	6	6	6	0.63245553
24/1/68 6:00AM	-	10	10	10	10	10	10	0
24/1/68 6:00PM	-	10	10	10	10	10	10	0
25/1/68 6:00AM	-	10	10	9	10	10	9.8	0.4
25/1/68 6:00PM	-	10	9	9	10	9	9.4	0.48989795
26/1/68 6:00AM	-	9	9	9	9	9	9	0
26/1/68 6:00PM	-	9	8	8	8	8	8.2	0.4
27/1/68 6:00AM	-	8	7	8	6	8	7.4	0.8
27/1/68 6:00PM	-	7	6	7	6	7	6.6	0.48989795
28/1/68 6:00AM	-	7	6	7	7	7	6.8	0.4
28/1/68 6:00PM	Sixth	6	6	6	7	6	6.2	0.4
29/1/68 6:00AM	-	10	10	10	10	10	10	0
29/1/68 6:00PM	-	10	10	10	10	10	10	0
30/1/68 6:00AM	-	10	10	10	10	10	10	0
30/1/68 6:00PM	-	9	10	9	9	10	9.4	0.48989795
31/1/68 6:00AM	-	9	10	8	9	10	9.2	0.74833148
31/1/68 6:00PM	-	8	9	7	8	8	8	0.63245553
1/2/68 6:00AM	-	8	8	6	7	7	7.2	0.74833148
1/2/68 6:00PM	-	7	8	6	7	7	7	0.63245553
2/2/68 6:00AM	-	7	7	5	6	6	6.2	0.74833148
2/2/68 6:00PM	-	7	7	5	5	5	5.8	0.9797959
Average		8.41666667	8.5	8.31666667	8.3	8.4	8.38666667	0.0725718

Figure 25: Soil moisture measuring result (Formula 4)

Date	Watering	Formula 4						
		Pot 1	Pot 2	Pot 3	Pot 4	Pot 5	Average	S.D.
4/1/68 6:00AM	First	4	4	4	4	4	4	0
4/1/68 6:00PM	-	10	10	10	10	10	10	0
5/1/68 6:00AM	-	10	10	10	10	10	10	0
5/1/68 6:00PM	-	10	10	10	10	10	10	0
6/1/68 6:00AM	-	10	10	10	10	10	10	0
6/1/68 6:00PM	-	10	10	10	10	10	10	0
7/1/68 6:00AM	-	10	9	10	10	10	9.8	0.4
7/1/68 6:00PM	-	9	9	10	10	10	9.6	0.48989795
8/1/68 6:00AM	-	7	8	6	8	7	7.2	0.74833148
8/1/68 6:00PM	Second	5	5	5	7	6	5.6	0.8
9/1/68 6:00AM	-	10	10	10	10	10	10	0
9/1/68 6:00PM	-	10	10	10	10	10	10	0
10/1/68 6:00AM	-	10	10	10	10	10	10	0
10/1/68 6:00PM	-	10	10	10	10	10	10	0
11/1/68 6:00AM	-	10	10	10	10	10	10	0
11/1/68 6:00PM	-	10	10	10	10	10	10	0
12/1/68 6:00AM	-	10	10	9	10	10	9.8	0.4
12/1/68 6:00PM	-	9	9	9	10	9	9.2	0.4
13/1/68 6:00AM	-	9	8	9	8	6	8	1.09544512
13/1/68 6:00PM	Third	8	7	6	6	6	6.6	0.8
14/1/68 6:00AM	-	10	10	10	10	10	10	0
14/1/68 6:00PM	-	10	10	10	10	10	10	0
15/1/68 6:00AM	-	10	10	10	10	10	10	0
15/1/68 6:00PM	-	9	10	10	9	10	9.6	0.48989795
16/1/68 6:00AM	-	8	9	8	9	10	8.8	0.74833148
16/1/68 6:00PM	-	8	9	8	8	9	8.4	0.48989795
17/1/68 6:00AM	-	8	9	7	7	8	7.8	0.74833148
17/1/68 6:00PM	-	7	9	6	7	8	7.4	1.0198039
18/1/68 6:00AM	-	7	8	6	6	7	6.8	0.74833148
18/1/68 6:00PM	Fourth	5	7	7	6	6	6.2	0.74833148
19/1/68 6:00AM	-	10	10	10	10	10	10	0
19/1/68 6:00PM	-	10	10	10	10	10	10	0
20/1/68 6:00AM	-	10	10	10	10	10	10	0
20/1/68 6:00PM	-	10	10	10	10	9	9.8	0.4
21/1/68 6:00AM	-	9	10	9	9	9	9.2	0.4
21/1/68 6:00PM	-	8	9	9	9	9	8.8	0.4
22/1/68 6:00AM	-	8	9	8	8	8	8.2	0.4
22/1/68 6:00PM	-	8	8	7	7	8	7.6	0.48989795
23/1/68 6:00AM	-	7	7	7	6	7	6.8	0.4
23/1/68 6:00PM	Fifth	6	7	7	7	6	6.6	0.48989795
24/1/68 6:00AM	-	10	10	10	10	10	10	0
24/1/68 6:00PM	-	10	10	10	10	10	10	0
25/1/68 6:00AM	-	10	10	10	10	10	10	0
25/1/68 6:00PM	-	10	10	9	9	10	9.6	0.48989795
26/1/68 6:00AM	-	9	9	9	9	10	9.2	0.4
26/1/68 6:00PM	-	9	8	9	8	9	8.6	0.48989795
27/1/68 6:00AM	-	8	8	8	8	8	8	0
27/1/68 6:00PM	-	8	7	7	8	7	7.4	0.48989795
28/1/68 6:00AM	-	7	6	7	7	7	6.8	0.4
28/1/68 6:00PM	Sixth	7	6	6	6	6	6.2	0.4
29/1/68 6:00AM	-	10	10	10	10	10	10	0
29/1/68 6:00PM	-	10	10	10	10	10	10	0
30/1/68 6:00AM	-	10	10	10	10	10	10	0
30/1/68 6:00PM	-	9	10	10	9	10	9.6	0.48989795
31/1/68 6:00AM	-	9	10	10	9	10	9.6	0.48989795
31/1/68 6:00PM	-	8	9	9	8	8	8.4	0.48989795
1/2/68 6:00AM	-	8	8	8	7	7	7.6	0.48989795
1/2/68 6:00PM	-	8	8	6	7	6	7	0.89442719
2/2/68 6:00AM	-	8	7	5	7	6	6.6	1.0198039
2/2/68 6:00PM	-	7	7	5	6	5	6	0.89442719
Average		8.73333333	8.88333333	8.58333333	8.65	8.68333333	8.70666667	0.10088497

Figure 26: Soil moisture measuring result (Formula 5)