Design Improvements in Underground Watering System for Small Local Farming Industries

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Abstract. The implementation of underground watering system is basically to supply crops with enough quantities of water. In Malaysia, most farming industries use sprinkler irrigation system. The water is only distributed over the surface whilst the roots actually need water the most. Thus, this research is conducted to design the improvements of watering system for small local farming industries by using underground watering system. Design improvements of the watering system had been done using CATIA software. The design had been fabricated using rapid prototyping/3D printer, tested and evaluated by conducting experiments. Four different plants were prepared and labelled as Plant A, Plant B, Plant C, and Plant D. Plant A and Plant C were not be equipped with the underground watering device while Plant B and Plant D were equipped with the device. The growth of every plant is measured in terms of height, number of newly grown leaves, number of flowers and number of fruits for the duration of 60 days. The plant equipped with the device has the quickest growth measurement (59.68%), continued to produce new leaves rapidly (89.20%), and produced the most number of flowers (19 flowers) and fruits (15 fruits) when compared with the plants without the underground watering device. The difference in growth development is very significant. Therefore, the underground watering system does have a positive impact in nourishing the plant from the root efficiently and can be used productively in small local farming industries.

1. Introduction

Irrigation is important to agriculture. From ancient to modern era, irrigation has existed for as long as humans have been nurturing plants. In simple terms, irrigation can be defined as the replacement or supplementation of rainwater with another source of water. In addition, irrigation is one of a major section to contribute in the growing of agricultural plants. In Malaysia, there are many types of irrigation implemented for agriculture sectors. They cover from traditional-low scale methods to modern high tech approaches. For small local farming industries, sprinkler irrigation system is common. However, there are some problems associated with the usage of sprinkler. The water droplets are only sprinkled over the surface of the soil, which may lead to water loss due to evaporation under high wind and high temperature. As a consequence, the absorption rate of water by the roots may become slower. Additionally, sprinkler system does not contribute significantly in terms of economic value as the initial cost of equipment is high. The standard price for a set of sprinkler system in market usually ranges from RM 300 to RM 700.
Interconnected water filled micro pores in soil causes the water movement through soil. Therefore, water flows from soil to root at a rate depending on the water potential gradient between soil and plant which is affected by plant water need, hydraulic conductivity of the soil, soil type and soil water content [1]. Several designs were developed in the past to encourage underground watering system as can be seen in Figure1 [2-4]: Solar powered plant watering system functions as an automatic plant watering system that uses solar energy rather than the power supply. It was invented after analyzing the normal process of watering plant which was not effective and caused difficulty, was time consuming and experienced water inefficiency [5]. However, these designs are limited to water supply to the roots only; the nutrients from the fertilizers supply have not been considered. Fertilizers were still placed at the top surface and take a longer time to dissolve before it gets absorbed by the roots.

![Image](image1.png)

**Figure 1.** (a) Vertical [2] (b) Conical [3] (c) Horizontal [4] Underground Watering Systems

The research work presented here focuses on the improvement of the design of current underground watering system that provides just the required amount of water and fertilizers to the plant. This will help in saving water as well as saving money. It also provides water directly to the root area. Roots are essential for the survival and healthy growth of plants, for it is directly involved with the absorption of water, minerals and nutrients. Thus, when the water and fertilizers goes underneath the soil, the absorption rate will increase. Moreover, it will help in maintaining a clean landscape since the water is directly delivered to the root area. It is expected that the new design of watering system will help improve the productivity of the local farming industries.

2. Methodology
2.1 Phase 1: Conceptual Design
Conceptual design is the process by which the design is initiated, carried to the point of creating a number of possible solutions. The designs of the underground watering device are sketched, and narrowed down to a single best concept (Figure 2) using CATIA after the benefits and drawbacks of the ideas are carefully studied (Table 1).

| Benefits                                      | Drawbacks                                           |
|----------------------------------------------|-----------------------------------------------------|
| A large amount of water can fill up the device. | The shape of the body is slightly difficult to drive into the soil, so it requires burying |
| Present of holes for water flowing.          |                                                     |
| Connecting pipe for water flowing from the water source. |                                                     |
2.2 Phase 2: Embodiment Design
Structured development of the chosen design has been carried out in this phase. Decisions are made on strength, material selection, size, shape, and spatial compatibility of the device.

2.3 Phase 3: Detail Design
In this phase, the chosen design is brought to the stage of a complete engineering description of a tested and producible product. Missing information is added on the arrangement, form, dimensions and tolerances, surface properties, materials, and manufacturing processes of each part.

2.4 Rapid prototyping
To fabricate the product, 3D printer (uPrint SE Plus 3D Printer) was used. Two types of materials were used; the support material and the model material. The support material used was SR-3™ XL Soluble Support while the model material was ABS-P43™ XL Model (Ivory). It takes approximately 6 hours to build up the body and 54 minutes to build up the cap.

The body and the base of the device were drilled using hand drill (Bosch GSR 14 4-2 Professional). The purpose of drilling the body is to make holes around the body to allow water flow through. There are 18 holes with diameter 2 mm distributed around the body (Figure 3). At the base of the device (Figure 4), there are 9 holes with diameter 3 mm to allow fertilizer to flow through and easily absorbed by the soil.
2.5 Testing and Evaluation
For the testing and evaluation of the device, four lime plants of the same type were prepared and labelled as Plant A, Plant B, Plant C, and Plant D (Figure 5). Plant A and Plant C were not equipped with the device while Plant B and Plant D were equipped with the device. The soil used for all the plants was from same source and was of same quantity. The plants are placed at the same location where they get necessary sunlight. 500 ml of water is used to water every plant at the same time every day in the morning. Plant A and Plant C were sprayed on the surface whereas Plant B and Plant D were watered by filling the device with water. The quantity of fertilizer used is 0.05 grams for all plants once a week.

The initial conditions of the plant were recorded; height, number of leaves, number of flowers and fruits (if any). The growth of every plant was measured using measuring tape in millimeters (mm) as well as the newly grown leaves, number of flowers and number of fruits. All data is recorded every day. Pictures of every plant were taken to observe the growth. Pictures of every new leaves, new flowers and new fruits are also taken. The weather in the morning and evening is recorded. The data obtained are tabulated and graphs are plotted for analysis.

| PLANT A | PLANT B | PLANT C | PLANT D |
|---------|---------|---------|---------|

Figure 5. Plant A, Plant B, Plant C, and Plant D

3. Results and Discussion
3.1 Growth Measurement
Plant D has the highest percentage of growth measurement which is 59.68%, followed by Plant B with 53.13%, Plant C (40%) and Plant A has the lowest growth measurement which is 31.34% for the duration of 60 days. According to Figure 6, Plant B is growing faster than Plant A as Plant B showed difference in growth measurement as early as in day 3 and continued to grow quicker. In the meantime, Plant A showed difference in growth measurement during day 11. It can be observed in the graph that Plant A has slower growth and stopped growing from day 51 until day 60 which is about 10 days. Meanwhile, Plant B showed consistent of growth although it stopped growing from day 56 until day 60 (5 days). It can be stated that Plant B that comes with the device has helped in speeding up the growth of the plant.

Plant A and Plant C (without device) both showed difference in growth measurement starting from day 11. Both Plant A and Plant C shared quite similar growth measurement even though the graph displayed that Plant C grown faster than Plant A. Plant A stopped growing from day 51 until day 60 while Plant C continued to grow after day 53. Both Plant A and Plant C are without device. In this case, Plant C is healthier than Plant A based on the growth measurement of both plants.
Both Plant B and D are equipped with the device. Plant B showed difference in growth measurement in day 3 while Plant D showed difference in growth measurement during day 4. Plant B and Plant D have parallel growth measurement as their difference is only 5 mm to 15 mm only. It can be assured that Plant D grows slightly quicker than Plant B.

3.2 Growth of Leaves
Plant B (with device) has the highest percentage of newly grown leaves which is 89.20%, followed by Plant A with 85.28% of newly grown leaves, Plant D (with device) with 81.38% new growth and Plant C has the lowest newly grown leaves which is 72.56% for the duration of 60 days as seen in Figure 7. Plant A produced new leaves earlier than Plant B. Plant A produced new leaves during day 9 while Plant B produced new leaves during day 11. During day 19, Plant B produced more leaves than Plant A; Plant B had 18 new leaves and Plant A had 11 new leaves. This might due to Plant B has grown faster. Both plants continued to produce new leaves until day 38 where only plant B had loss some leaves; about 13 leaves. It is assumed that this is because strong winds and heavy rain. Starting day 46, Plant B continued to produce more new leaves until day 60.

Plant A and Plant C produced new leaves at the same day; day 9. The graph showed that plant C produced more new leaves than Plant A. It could be because Plant C grown faster than Plant A. During day 48, Plant A produced 90 new leaves which is 9 more new leaves than Plant A which produced 81 new leaves. It can be assumed that because plant A grown faster than Plant C during day 48 (Plant A growth measurement is 85 mm while Plant C growth measurement is 80 mm). Plant A continued to produce higher number of new leaves than Plant C until day 60.

3.3 Growth of Flowers
Plant A had flowers until day 27 only, Plant D had flowers from day 19 until day 30, no flowers from day 31 until day 45, and again Plant D had flowers from day 46 until day 57. This condition showed that Plant D (with device) is better in producing flowers than Plant A. This is due to Plant D is healthier than Plant A based on the growth measurement of both plants (Figure 8).

Plant B had flowers until day 30 only, Plant C had flowers from day 7 until day 27, no flowers from day 28 until day 45, and again Plant C had flowers from day 46 until day 59. This condition shows that Plant C is better in producing flowers than Plant A (both without device). Although Plant B is equipped with the device, some conditions should be taken into consideration as why Plant C produced more flowers than Plant B. It can be assumed that Plant C is basically healthier than Plant B from initial condition, and Plant C had more flower buds than Plant B. Thus, Plant C produced faster and higher number of flowers that Plant B. However, Plant D is better in producing flowers than Plant B. Both plants are equipped with the device. Nonetheless, Plant D produced more flowers than Plant
B. It can be deduced that Plant D is healthier than Plant B. Plant D also produced many flowers at a time when compared with Plant A and C (without device).

![Growth of Flowers](image1)

![Growth of Fruits](image2)

**Figure 8.** Graph for the Growth of Flowers

**Figure 9.** Graph for the Growth of Fruits

### 3.4 Growth of Fruits

The maximum number of new fruits produced by Plant A is 4, and Plant B produced 3 new fruits as the maximum. The maximum number of new fruits produced by plant C is 7 and Plant D has produced maximum 15 new fruits for the duration of 60 days. All plants started to produce fruits from day 34. It is consistent with no flowers produced for all plants during day 34 (Figure 9).

It is observed that the number of fruits of all plants (A, B, C and D) has decreased by the end of 60 days. It is likely due to the fruits are new and fell because of strong winds and heavy rain. Plant D had the highest number of fruits compared to other plants. It can be assumed that Plant D is the healthiest and with the aid of the device, Plant D is capable of producing more fruits.

### 4. Conclusion

Plant D that is equipped with the device has the quickest growth measurement which is 59.68%, and continued to produce new leaves rapidly even though the percentage is not the highest. However, Plant B that is also equipped with the device has the highest percentage of newly grown leaves which is 89.20%. Plant D also produced the most number of flowers which is 19 flowers and highest number of fruits which is 15 fruits. The device functions well as an underground watering system for the plant by absorbing necessary and sufficient water, minerals and nutrients effectively and efficiently. Furthermore, it can help in enhancing the cleanliness of the outer surface of the ground by preventing muddiness as a result from surface watering. This underground watering device can be beneficial to the small local farming industries.

### 5. References

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