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Original Research Article

Monitoring of Soil Moisture Using Smart Irrigation System in Chinese Cabbage (*Brassica Chinensis*) Cultivation

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Abstract: Smart irrigation system is a Precision Agriculture (PA) based device that can automate the irrigation process by analysing soil moisture. The sensor used is a soil moisture sensor that acts as the brain to the system, which will control the whole irrigation system. This research was conducted in the irrigation workshop at UITM Malacca, Jasin Campus, with four treatments and four replications in each treatment. The treatments were T1: manual irrigation (regular planting), T2:40% of soil moisture content, T3:45% of soil moisture content, and T4:50% of soil moisture content. The experimental design used in this study was completely randomized (crd). The parameters involved in this study were plant height, number of leaves, root length, fresh weight, and dry weight of Brassica Chinensis. The data were analyzed using SPSS statistical version 26, and the data analysis involved was average means, analysis of variance (ANOVA), and post hoc test (Bonferroni test). The result shows a significant difference between treatments for plant height, number of leaves, fresh weight, and dry weight parameter since the significance value is less than (0.05), *p*-value >α, 0.05. While no significant difference between treatments for root length. For all parameter measures of *Brassica Chinensis*, which was height, the number of leaves, length root, fresh weight, and dry weight shows that T4 had the highest mean, while T2 had the lowest mean. In conclusion, T4 (50% of soil moisture content) was the best percentage to grow a healthy plant.

Keywords: Precision Agriculture, Brassica Chinensis, Smart Irrigation system, Soil Moisture Sensor

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1. Introduction

Smart farming is a concept of farm management that uses modern information and technology to improve the quality and quantity of agricultural products. The innovation in smart agriculture needs more knowledge and creativity. New farming technologies also require more professional skills. The Internet of Things and Cloud Computing are new technologies that would optimize this innovation and bring more automated computers and artificial intelligence in agriculture (Wolfert *et al.*, 2017). Irrigation is the supply of artificial water to the land for agricultural production. The efficacy of irrigation will directly influence the entire growth process. Smart and intelligent irrigation program system that will allow agriculture to maximize water use and only irrigate if necessary, when and where necessary only (Khriji *et al.*, 2014).

Soil moisture is essential in the agriculture sector, particularly in decision-making (Raza *et al.*, 2019). The irrigation system is heavily reliant on the accuracy of soil moisture sensing technology to ensure adequate water availability and to prevent over-irrigation, which can contribute to water waste. Monitoring soil moisture is critical for ensuring that water resources are used efficiently (Anabel *et al.*, 2019).

The soil moisture meter is used to measure soil moisture when the soil has a water shortage in the soil. This sensor can help the system irrigate the soil and plant, depending on the programmed system. These soil moisture sensors are productive tools in measuring soil moisture to determine crop growth (Garg *et al.*, 2018). This sensor measures the water content at the root zone and is very useful in the irrigation program. The innovative irrigation system is an IoT-based device automatically measuring soil moisture in the irrigation system. The soil moisture data and information will be displayed in a graphical form. The microcontroller, such as the Arduino Mega, which serves as the system's brain, will control the entire irrigation system. The rest of the irrigation system will be controlled automatically by Arduino.

Water is one of the essential crop-production resources. Today, water insufficiency and scarcity affecting agricultural production affect many countries worldwide. Climate change results from increased water scarcity and drought conditions (Mancosu *et al.*, 2015). During irrigation, a sufficient amount of water is critical in crop production to ensure crop growth, quality, and production. The water control system fails when there is no automatic controlling system (Aishwarya, 2017). IoT and smart farming improve internal processes and reduce production risk (Walter *et al.*, 2017).

Various types of irrigation methods can be widely categorized into surface irrigation, sub-surface irrigation, sprinkler irrigation, and drip irrigation systems. (Sanjeev Gadad, 2017). All this type of irrigation has their effectiveness, advantages, and disadvantages. There are several ways that IoT can improve agriculture, such as information and data collection being collected by smart agriculture sensors (Nayyar & Puri, 2017). The collected data include weather conditions, crop growth progress, soil quality, and amount of yield in different areas. Besides, IoT and smart farming create better control over internal processes and lower production risk (Walter *et al.*, 2017).

Several types of IoT sensors and IoT applications are very useful in agriculture. The IoT sensor can monitor the climate condition (Corrales *et al.*, 2018). One of the most popular smart agriculture gadgets is weather stations that combine various smart farming sensors. The sensor is usually located across the field. It is used to collect various types of data from the environments that can map the climate conditions and take the necessary measure to enhance their capability.

Besides, IoT sensors also can be implemented at greenhouse automation to automatically adjust the condition required to scientific discipline with the parameters. The irrigation, lighting, temperature, and others can be remotely controlled and adjusted (Dasgupta ***et al.***, 2018). The objective of this studies to determine the best percentages of soil moisture for effective growth of Brassica Chinensis.

2. Materials and Methods

2.1. Experimental Set-up

A complete irrigation moisture system was used to run the experiment, an automatic irrigation system to irrigate the soil at the level of moisture percentage needed (Figure 1). A moisture sensor was used to measure the moisture content in the soil. The system will automatically irrigate the soil when the sensor detects dry conditions or lower moisture. After that, the Arduino Mega was used in the experiment that functioned as the brain of this system, and the brain-controlled all the input sensors and display devices.

(a) (b)

(c)

Figure 1. (a) The whole system (b) moisture sensor (c) misting irrigation.

In addition, a control panel with a screen display was used to run this experiment (Figure 2). This tool makes it easy to run experiments where the sensors can be adjusted to the desired level. It also allows to turn on and off the irrigation system's valves. The irrigation sensor moisture system also necessitates using a water pump and a piping system with a valve. The water pump must move water from the tank to the piping system and then to the soil to irrigate it. The valve that controls water flow from the piping system was modified to irrigate the soil with a mist irrigation technique.

Figure 2. The control panel of the whole system

2.2. Treatment Application

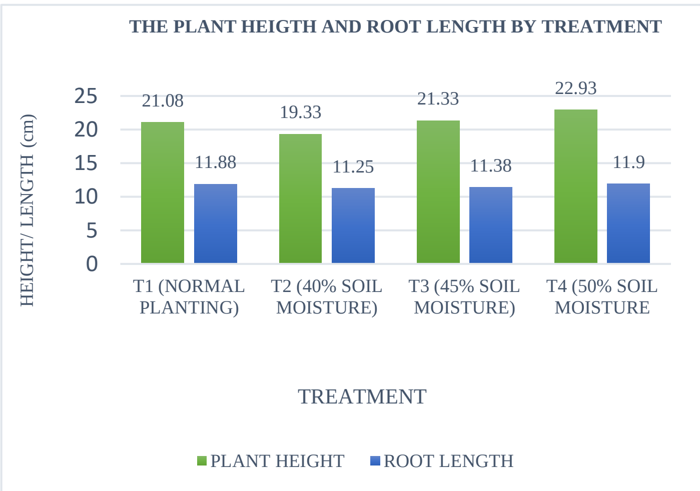
All the treatments applied in this research and experiment used complex fertilizer, NPK green, which contains nitrogen, phosphorus, and potassium. The ratio for this NPK green is 15-15-15 that suitable for vegetables and at the early stage of plant growth. This additional fertilizer increases the plant's growth and ensures the plant grows well with sufficient nutrients. For this experiment, there are four treatments, which for the T1 (regular planting) is used for control. The plant was watering twice a day, early morning and late evening every day. Three soil moisture levels were determined according to the treatments: T2: 40% soil moisture, T3: 45% soil moisture, and T4: 50% soil moisture. The organic soil used to irrigate is has 42 percent of water holding capacity. The experimental design with four treatments and four replications in each treatment is using Completely Randomized Design (CRD) with five (5) parameters was taken along this research that includes the plant height, number of leaves, root length, fresh weight, and dry weight (Figure 3).

Figure 3. Parameters of the plant are recorded every week.

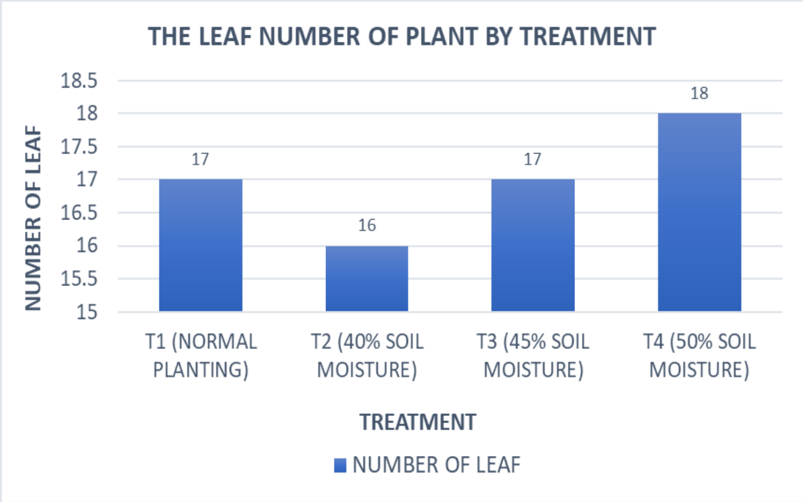
3. Results

3.1. The Measurements of The Features

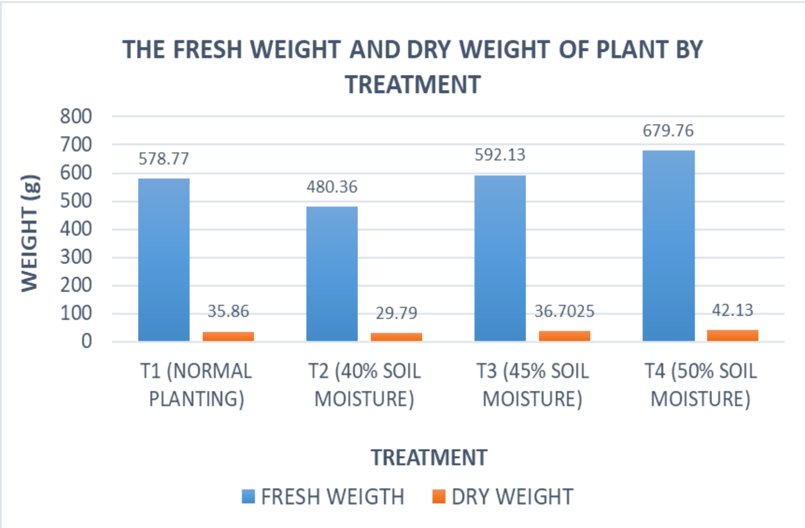
Figure 4(a) shows the means of the plant height and root length for the T1 (regular planting), T2 (40% soil moisture), T3 (45% soil moisture), and T4 (50% soil moisture). The result shows that T4 had the highest plant height (22.93 cm) and root length (11.90 cm). While Figure 4(b) shows the means of the leaves number of plants. The result shows T4 had the highest valve in several leaves, 18, while the lowest result was T2 with 16 leaves. Figure 4(c) shows the means of the plant's fresh and dry weight. The result shows T4 was the highest result in both fresh weight (679.76 g) and dry weight (42.13 g), while the lowest result was T2 for both fresh weight (480.36 g) and dry weight (29.79 g).



(a)



(b)



(c)

Figure 4. (a) The plant height and root length of the plant by treatment; (b) The leaf number of plants by treatment; (c) The fresh weight and dry weight of plant by treatment.

Table 1 shows the summary of output from the ANOVA test for all parameter data include the plant height, number of leaves, root length, fresh weight, and dry weight. The ANOVA test for the plant height, number of leaves, fresh weight, and dry weight showed the result of one-way ANOVA that there was a significant difference between the plant height for all the treatments T1, T2, T3, and T4 with a p-value less than alpha (α) 0.05. Meanwhile, for root length, the result of one-way ANOVA showed no significant difference between the treatment with a p-value larger than 0.05. The difference between condition means is different due to change and is probably due to the independent variable manipulation.

Table 1. The results of Analysis of Variance (ANOVA) for parameters data

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Plant Height	Between Groups	26.067	3	8.689	6.505	.007
	Within Groups	16.030	12	1.336		
	Total	42.097	15			
Number of Leaves	Between Groups	8.000	3	2.667	4.000	.035
	Within Groups	8.000	12	.667		
	Total	16.000	15			
Root Length	Between Groups	1.355	3	.452	1.105	.385
	Within Groups	4.905	12	.409		
	Total	6.260	15			
Fresh Weight of Plant	Between Groups	79995.848	3	26665.283	6.123	.009
	Within Groups	52259.955	12	4354.996		
	Total	132255.803	15			
Dry Weight of Plant	Between Groups	306.378	3	102.126	6.119	.009
	Within Groups	200.285	12	16.690		
	Total	506.663	15			

*significant at 5% level

4. Discussions

Two methods have been carried out to irrigate the soil of *Brassica Chinensis* involving manual irrigation, which is a regular planting that the soil is irrigated or watered early in the morning and late in the evening, and a smart irrigation system that uses a soil moisture sensor to monitor soil moisture at any time required.

The best percentage of soil moisture content from smart irrigation system is alsoT4 (50% moisture content) rather than T2 (40% moisture content) and T3 (45% moisture content). Hence, the growth of *Brassica Chinensis* plant for T4 is the highest means for all parameters, including plant height, number of leaves, root length, fresh weight, and dry weight. There is a statistically significant difference between the plant parameters treatments: plant height, number of leaves, fresh weight, and dry weight. At the same time, there is no statistically significant difference between treatments to root length. The difference between condition means is different due to change and is probably due to the independent variable manipulation.

This system demonstrated that the water intake of *Brassica Chinensis* could be controlled and monitored for optimal growth. *Brassica Chinensis* is sensitive to nitrogen (N) and water stress because it is a leafy plant with a succulent stem (Kamarudin *et al.*, 2014). It requires constant irrigation to achieve optimum production because leaf production is linked to leaf expansion, the most sensitive physiological process to water stress (Paulus *et al.*, 2019).

Plant stress caused by biotic or abiotic factors can reduce yield and directly impact growth (Kim & Glenn, 2017). Water, which contributes to soil moisture, is one of the abiotic factors affecting crop production (Raza *et al.*, 2019). In both flooding and drought conditions, most of the plants will perish. It is critical to maintaining soil moisture with a wide range of plant available water (Luke *et al.*, 2019).

5. Conclusions

The automated irrigation system based on soil moisture has been successfully tested using the Arduino Mega. The system has been tested to ensure that it operates automatically. The moisture sensors measure the soil's moisture percentage level (water content) concerning the *Brassica Chinensis* plants. The moisture percentage levels were 40%, 45%, and 50%. Finally, T4, 50% of the soil moisture content, was the best moisture content for *Brassica Chinensis*.

Supplementary Materials: The following are available online at http://www.journals.hh-publisher.com/index.php/AAFRJ//xxx/s1, Figure S1: title, Table S1: title.

Author Contributions: A short paragraph specifying their individual contributions must be provided for research articles with several authors. The following statements should be used "Conceptualization, A.Yusoff. and S. M. Shamsi.; methodology, A.Yusoff.; software, A. Yusoff.; validation, A.Yusoff., S.M. Shamsi.; formal analysis, A.Yusoff.; investigation, A.Yusoff.; resources, A.Yusoff.; data curation, A.Yusoff.; writing—original draft preparation, A.Yusoff.; writing—review and editing, S. M. Shamsi.

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