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Effect of electrical conductivity and Nutrient Concentrations of Soilless Media Monitored with the Internet of Things (IoT) Sensor Nodes on Growth of Rock Melon

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Abstract: The challenges of managing traditional agricultural planting have prompted the implementation of the internet of things (IoT) to enable real-time detection and intelligent management of crop growth. The IoT-based monitoring solution was purposely designed to gauge the moisture content, and electrical conductivity (EC) in newly prepared soilless media, The newly soilless media were codded M1 which contains proportions of CD, burnt rice husk, and perlite at different percentages. The M2 contains CD, burnt rice husk, and perlite, M3 contains Coconut coir dust, vermiculite, and perlite, M4 had CD, perlite while M5 designated as control evaluation had 100% CD. The experiment was conducted in a greenhouse. The nutrient concentrations and EC levels were determined with a customized portable internet of things (IoT) system. Relevant real-time agronomic data were collected. The highest EC level was observed in M2 and M3 with 1.4 dS/m and 1.3 dS/m, respectively. Soilless medium M2 and M3 noticeably showed the highest nitrogen and phosphorus concentration and were significantly different from M1, M4 and M5 while the highest potassium concentration was recorded in M2. The EC and nutrient concentration translated into the highest leaf area, plant height, highest number of leaves, and greater leaf weight. Total fresh fruit weight was significantly greater in soilless media M2 3.17 kg/plant and M3 3.34 kg/plant. The highest soluble solid content (SSC) was influenced by the M2. Consequently, the proportions of the materials in both soilless media could be considered for achieving robust growth and fruit quality of rockmelon.

Keywords: EC levels, Fruit quality, IoT Sensor nodes, Rockmelon, Soilless media

1. Introduction

For many crops particularly vegetables and fruits was challenging to manage soil-borne diseases due to increased environmental concerns and restrictions on fumigant use (Wang et al., 2016). More researchers are aware of soilless culture's capacity to enable efficient and intensive plant production (Barrett et al., 2016). Additionally, soilless systems have higher yields and use water and nutrients more efficiently than traditional soil-grown systems (Che Nordin et al., 2022; Raviv et al., 2002). Conditions in the growing medium are crucial for the growth and development of plants (Ab Rauf & Shahruddin, 2022; Bartczak et al., 2007). This is partially due to the substrate's nutritional availability, which significantly affected the growth of the shoots and roots (Leskovar and Othman, 2016). Unfortunately, coconut coir dust (CD), the most widely used soilless medium for planting vegetables and fruits, falls short in some areas. The CD is free

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of weeds and pathogens. It has excellent drainage, a high cation exchange capacity (C.E.C.), a high electrical conductivity (EC), and good root zone aeration, making it a suitable growth medium. Specific challenges with CD include high salinity, excessive potassium concentration, and low pH. This is the rationale behind numerous researchers' addition of various organic and inorganic elements to CD, which has influenced plant growth and productivity. Apart from CD, several soilless substrates have been formulated.

Strawberry plants grown on rock wool produced fresher and drier biomass than plants grown in soilless coconut substrate and peat-pine bark (1:1 v/v) (Bartczak et al., 2007). In contrast to plants grown in other substrates, Ebrahimi et al. (2012) found that strawberry plants grown in CD and perlite substrate (1:1 v/v) had the highest levels of chlorophyll a and b, as well as carotenoid, in both old and young leaves. Furthermore, Salisu et al. (2020) discovered that soilless media made of perlite, vermiculite, and burnt rice husk (BRH) substantially impacted the number of leaves and leaf area. In a study on strawberries, strawberries planted in peat moss + perlite (4:1 v/v) had the maximum output, while those produced in CD + perlite (4:1 v/v) had the highest photosynthesis and fruit firmness. This suggested that perlite and vermiculite could be combined for high fruit production. It might significantly impact vegetables and fruit quality like watermelon.

Rockmelon (*Cucumis melo* L.) is one of Malaysia's significant economic crops and provides farmers with a considerable income (Ismail et al., 2020). The production of the fruit was varied. One possible reason is a poor soilless medium (Muhammad et al., 2017). Fertilization and effective pre-harvest procedures for controlling and boosting crop yield and nutritional quality for human consumption are two of the most helpful strategies. Soilless culture is essential since it allows for precise plant nutrition control (Rouphael et al., 2008). Drip irrigation methods in fertigation provide water and nutrients to plants in soilless media. Although this procedure is effective, it could waste water and nutrients if the correct EC of the fertilizer is not identified. Additionally, water-soluble fertilizers may cause the crop to absorb a lot of nutrients, which could reduce crop production (Pardossi et al., 2002). Usually, fertigation systems use a predetermined range rather than the ideal EC for fertilizer intake (Rouphael et al., 2005). Few studies look at how to mix organic or inorganic components to produce the most excellent fruit and how to monitor it with Internet of Things (IoT) sensor nodes. The microcontroller, Cortex-M3 96MHz 64kB, serves as the main CPU. Its single-core Central Processing Unit (CPU) operates at 160 MHz, and its Random-Access Memory has a capacity of 128 kB. (RAM) Serikul and others (2019). For the app to get the moisture, pH, and nutrient data from the NodeMcu ESP8266, the Firebase plugin needs to be installed in Android Studio. The software displays the moisture trend and the appropriate plant data levels throughout the day in real time. The primary goal of the monitoring system is to measure the E.C., nutrients, and moisture content of soil and soilless medium and relay the data to the user via the Firebase IoT platform (Noar and Kamal, 2017). There is not enough information on how soilless media, the EC and IoT sensor nodes for fruits and vegetables affect growth and quality. The agricultural industry can benefit significantly from IoT-based monitoring solutions. The primary goal of the monitoring system is to measure the EC, nutrients, and moisture content of soil and soilless medium and to relay the data to the user via the Firebase IoT platform (Noar and Kamal, 2017). This study evaluated the effects of various EC and nutrient concentrations in soilless media on growth and fruit quality. These were observed using IoT sensor nodes to determine how each soilless medium's EC and nutrients influenced the yield of rockmelons.

2. Materials and Methods

2.1 Preparation of the New Soilless Media

This study employed the conventional CD as a control treatment along with four newly formulated soilless media. The materials were chosen following Miller and Jones' (1995) recommendation on materials for developing growth media for greenhouse crops. The newly formulated soilless media were coded M1, M2, M3, M4, and M5. The formulation was carried out at Agricultural Field B of Sultan Idris Education University (UPSI) Berkeley method (Rakocy et al., 2009; Adekunle, 2017). Table 1 shows the proportions of the components in each soilless media.

Table 1: Composition of different newly prepared soilless media and Coconut coir dust (control)

Soilless media	Soilless Formulations	% Components composition
M1	Coconut coir dust, burnt rice husk, perlite	75:15:10
M2	Coconut coir dust, burnt rice husk, perlite	75:20:5
M3	Coconut coir dust, vermiculite, perlite	75:15:10
M4	Coconut coir dust, perlite	75:25
M5	Coconut coir dust (CD)	100 (control)

Rock melon seeds were planted fowling the recommendation by Zulkarami et al. (2010). Seedlings were carried out for 14 days. Thereafter, seedlings of uniform size were placed in plastic bags with newly prepared soilless media, namely M1, M2, M3, and M4, as well as CD M5, which served as the control treatment with five replications using a randomized complete block design (RCBD). The Rockmelon took ten weeks to grow and was drip-irrigated twice daily. Data were collected at 3, 6, 9, and 10 weeks after transplanting. Fruit size, number of leaves, weight, and sweetness were all collected. REDtone International Bhd-Broadband providers in Malaysia developed a specific portable IoT system (Figure 1) to observe the soilless media's characteristics.

Fig. 1: The portable IoT Smart farming system by REDtone International Bhd-Broadband provider in Malaysia

The IoT system has all the necessary components and capabilities for real-time data collection. It is equipped with a LoRa transmitter to transmit data collected by the sensor nodes to the gateway node. The TTGO, T-Beam serves as the WSNs gateway node. The ThingsBoard platform can store any findings or recommendations about soilless media. The Internet of Things can be managed using this platform, which collects, analyze, and displays data. Rock melon grown on the soilless medium was monitored and kept in good health with the help of these processes and functions, making it easier for farmers to save sensor data in the cloud. Sharrar et al. (2021) described the IoT smart agricultural system's components and functions. The processes and activities of the built-in components work together to keep Rockmelon healthy on the soilless substrate. Farmers can easily use the cloud platform to store the data gathered from sensor nodes. As illustrated in Figure 2, the system was monitored on-site for EC, total dissolved solids (TDS) of nutrients, moisture content, and pH utilizing a cloud database.

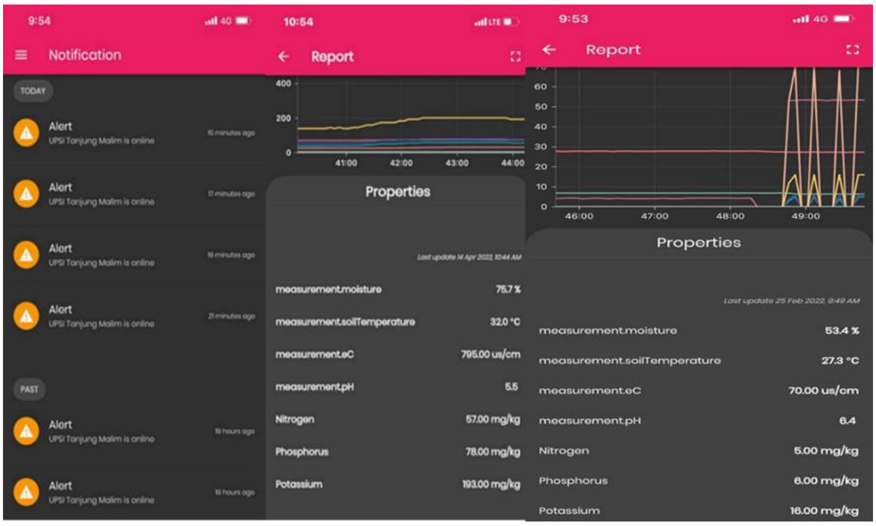

Fig. 2: E.C., moisture, pH and nutrient concentration readings from Portable IoT Smart Farming System

Figure 3 shows how different soilless media affect rockmelon yield. A randomized block design was used to generate and statistically analyze the data collected using SAS for Windows 9.0. The Least Significant Difference (LSD) analysis was used to compare the treatment.

Fig. 3: Influence of different soilless media on the growth of Rock Melon

3. Results and Discussion

The nutrient concentration and EC reading were routinely collected from the sensor nodes and a Tx LoRa transceiver through the cloud servers with the help of the portable IoT system. Table 2 presents the findings. The nitrogen content of the soilless medium M2 and M3 was significantly higher than M1, M4, and M5 (control), better and considerably varied from M1 in performance. The soilless medium M2 and M3 had the highest phosphorus contents, with M4 coming in second and differing significantly from M1 and M5. Burnt rice husk (BRH) and perlite were added, which resulted in a greater N concentration in M2 and M3. BRH has a high silica concentration, making it an excellent fertilizer additive since it improves soil fertility. It also boosts a higher capacity for retaining nutrients (Karam et al., 2021). Therefore, it has been demonstrated that BRH improves nutrient retention when mixed with other substances like coconut coir dust (Kulkarni et al., 2014). Perlite improves the soilless medium's porosity and helps preserve the stability of the nutrients, though excessive use of it is not advised (Kingston et al., 2020).

Regarding potassium content, M2 was the best and differed significantly from the other soilless medium, although plant grown on M1 and M3 was significantly greater and differed greatly from M4 and M5. The EC reading and its concentration on the various soilless substrates are shown in Table 1. M2 and M3 had the highest EC values, significantly higher than M4's 0.97 dS/m and were 1.4 dS/m, 1.3 dS/m, 1.16 dS/m, and 1.02 dS/m, respectively.

Table 2: Micronutrient concentration and E.C. levels in different soilless media

Treatments	N (mg/kg)	P (mg/kg)	K (mg/kg)	EC (dS/m)
M1	50.0c	66.0c	174.0b	1.17ab
M2	70.6a	72.7a	183.6a	1.4a
M3	70.02a	74.6a	174.8b	1.3a
M4	52.0bc	69.0b	167.0c	0.97b
M5	54.0b	64.0c	157.0d	1.09ab
LSD p<0.05	3.312	2.998	2.44	0.27

Means with the same letter are not significantly different

Plant height was measured from seven days after transplanting until 42 days later, and the means were taken. Table 3 presents the results. Compared to the other media, Soilless Medium M2 performed remarkably better, demonstrating that the quantity of BRH and perlite in the medium had a considerably favourable impact on the growth of rockmelon. The soilless media M1 has an E.C. of 1.29 (dS/m), which is significantly different from the plants grown in M1, M3, M4, and M5, which had E.C.s of 1.7 dS/m, 1.28 dS/m, 0.9 dS/m, and 1.09 dS/m, respectively. The similarly soilless media, M2, had the most significant number of leaves in a similar situation when the plant's number of leaves was recorded. M2 and M3 did not, however, significantly differ from one another. After the M2, the M3 had a notable high E.C. Except for M4, all the soilless media showed the maximum leaf weight of plants at maturity (42 D.A.T.); significantly, the medium recorded the lowest EC 0.97 dS/m in soilless media M2 and M3, which had the highest E.C., the maximum leaf area was seen. According to the findings, M2 and M3 were the soilless media with the highest levels of N and P. The tallest plants measured on both media were the plants. Notably, only soilless medium M2 recorded the highest K, which may have influenced its performance since it stood out from the other soilless media. The number of leaves and the weight of the leaves both followed a similar pattern. The leaf area, however, did not significantly differ between M1 and M2. Additionally, plants raised on both soilless media considerably differed from those planted on M3, M4, and M5.

Table 3: Effect of Nutrient Concentration and E.C. levels in different soilless media on the growth of Rockmelon

Treatments	Plant Height (cm)	Number of leaves	Leave weight (g)	Leaf Area (cm^2)
M1	5.7d*	37.02b*	27.16ab*	722.55a*
M2	6.96a	43.8a	27.59a	971.37a
M3	6.722b	41.88a	26.73ab	717.23b
M4	5.80c	37.98b	26.48b	694.38b
M5	5.70d	35.62b	27.31ab	721.91b
LSD p<0.05	0.0027	2.6210	1.09	54.733

*Means with the same letter are not significantly different

The nitrogen levels in M2 and M3 (70.6 mg/kg and 70.02 mg/kg, respectively) were noticeably greater than what was found in the other soilless media. As a result, M2 plants produced longer fruits, measuring 46.43 cm, followed by M3 plants, measuring 44.74 cm Figure 4a. The situation for P concentration was similar, although the highest K concentration was only found in M2. Potassium (K) enhances plant resilience to biotic and abiotic stressors and plays a crucial function in plant metabolism Sindhu and others (2010). The E.C. was more significant in the two soilless media. M2 (33.4 cm) and M3 (33.34 cm) planted considerably varied from those produced in M1, M4, and M5 and recorded the largest increased fruit diameter (Figure 4b). This demonstrates that the impacts of fruit quality were driven mainly by nutrient content and EC. According to Trejo-Téllez and Gómez-Merino (2012), there is a significant association between EC and the nutrients in the soilless media that may have a positive impact on plant growth. The results also showed that, in comparison to plants cultivated in soilless medium M1, M4, and M5, which measured 1.61 kg/plant, 1.93 kg/plant, and 1.83 kg/plant, respectively, total fresh fruit weights were significantly higher in soilless media M2 (3.17 kg/plant) and M3 (3.34 kg/plant) Figure 4c.

The most significant nutrient concentrations were found in these two soilless media, specifically N and P, while M2 had much higher K concentrations than the other soilless media. The primary factors influencing plant growth and development are Nutrients produced by osmotic stress surrounding the root and permitting a high concentration of nutrition and water absorption (Sang et al., 2018). The highest value of EC was obtained in the M2 and M3, which is near the expected levels given the high fruit quality observed. Early fruit development studies showed that raising EC from 1.5 to 2.4 dS/m significantly increased fruit quality (Veit-Köhler et al., 1999). Figure 4d shows the rockmelon sweetness measurement in plants grown in the oilless substrates. In soilless medium M2, which also recorded the greatest EC and nutrient contents, the highest soluble solid content (SSC) of 18.4% was found, followed by M3 SSC at 14.72%

much greater than other oilless media. The EC levels on these media, which ranged from 0.9 dS/m to 1.5, with the highest N, P, and K observed, may also be responsible for the sweetness of the plants. The EC levels of all the treated media and the sugar content of the fruits taken from those soilless media were more significant than 10%. The proportion of sucrose, which accounts for a substantial portion of the fruits' total sugar content, in the melons' overall fruit sugar content is remarkable (Villanueva et al., 2004). Generally speaking, Rockmelon with a brix rating of 10 or higher can be considered sweet. The Rockmelon's sweetness may have been due to the EC level, which was within 1.5 to 2.5 dS/m of the required level. According to Zulkarami et al. (2010)'s study, Rockmelon can obtain a high sweetness content on EC at 1.5 dS/m, based on the findings.

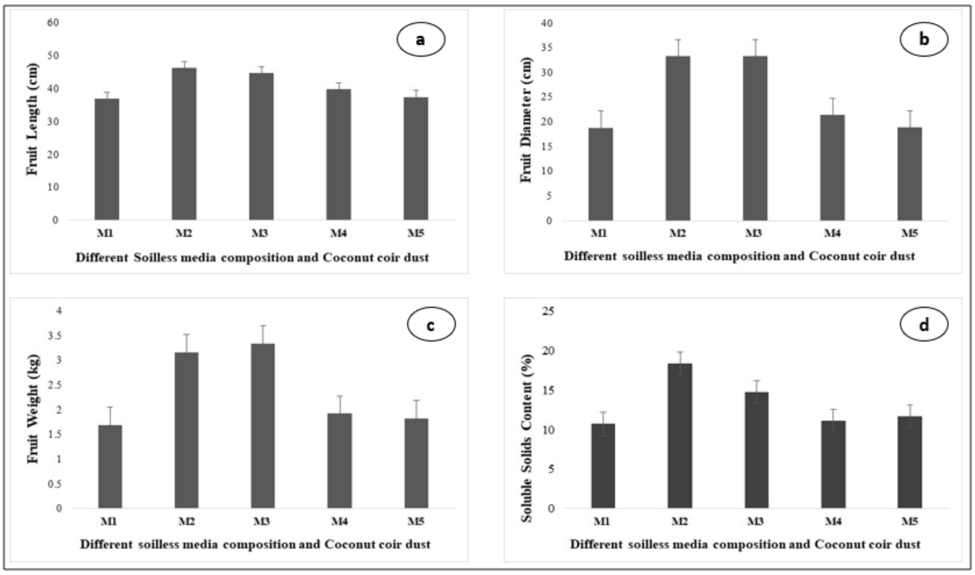

Fig. 4: (a.) Effect of different soilless media on fruit length, (b.) fruit diameter, (c.) fruit weight and (d.) the soluble solids content of rockmelons

4. Conclusion

Precision agriculture leverages IoT to gain insights and monitor crops by fusing sensor nodes with analytical tools. The research found that the material composition of soilless medium M2 produced considerable yields in rockmelon plants. The highest plant height, leaf count, and leaf area were recorded on this soilless medium. This soilless medium also impacted the most significant total fruit weight-cum-soluble solid content ever recorded. The soilless medium performed best because it had a higher N content and EC level. As a result, the proportion of BRH and perlite in M2 may be considered for better plant growth and fruit quality.

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