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Analysis of the Chlorophyll and Carotenoids Content in Brassica Chinensis Plants Using IoT-Based Sprinkle Irrigation

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ABSTRACT

The agricultural sector is currently witnessing the use of Internet of Things (IoT) to drive significant innovations across key interests, particularly irrigation. A sprinkler designed with an Arduino controller was developed in this study. The device is among the fastest growing agricultural irrigation systems. The plant studied is Brassica Chinensis, because this vegetable is one of the most commonly consumed vegetables by Indonesian people. However, emphasis is also placed on plant quality as an important consideration, not only on the device's operational performance. The purpose of this research was to compare the plant quality, including the dissolved solids, chlorophyll, carotenoid, and vitamin C using manual and Arduino-based sprinkler. As consequence, three treatment methods were employed, termed: the use of manual sprinkle, e.g. P0, and Arduino-based IoT sprinkler, described as P1 and P2. Under these conditions, the chlorophyll quality was comparable to the results obtained using the manual application. P1 is a situation where the sprinkler is manually set by the farmer via the app. Meanwhile, P2 uses a sprinkler which is automatically regulated by the system. Under these conditions, the chlorophyll quality generated with the IoT sprinkler was comparable to the results obtained using the manual application.

Keywords: app, chlorophyll, discharge, irrigation, system.

INTRODUCTION

The Brassica plant is an important vegetable with widespread cultivation across the world, and several huge benefits, including the ease of development, great taste, and high nutritional content (Hwang et al. 2020). In addition, a particular species with an extensive consumption rate is known as Pak Choy (brassica sinensis). However, water availability is a significant factor influencing the quality. According to (Park et al. 2021), insufficient water (drought stress) tends to reduce the important leaf nutrients, specifically glucosinolates, which play an essential role in cancer prevention. This factor is described as a major limiting abiotic factor affecting productivity and quality (Micheletto et al. 2007). Therefore, an effective irrigation management system is greatly required (Domashenko and Vasilyev 2018) (Singh 2014).

Indonesia is known to experience two seasons, termed dry and rainy seasons (Limantara and Noerhayati 2018). Therefore, efficient policies are required to regulate the irrigation practices, in order to preserve water, particularly during dry seasons.

In addition, the country's water supply level tends to decline drastically, due to lower river tides (Chanseetis et al. 2005), (TAKEDA et al. 2019), (Pamungkas, Hatou, and Morimoto 2014) IoT will open a door for smart services and new wireless architecture (Van Nguyen, Nguyen, and Do 2021).

The COVID-19 pandemic is assumed to instigate the deployment of IoT-based irrigation networks (Mona 2020), (Al Farizi and Harmawan 2020). The process is conducted remotely (Fraga-Lamas et al. 2020), and is therefore considered as a modern indispensable initiative (Vitali et al. 2021),(TANIGAKI et al. 2017) Several devices are employed in IoT-based sprinkler (Islam, Ray, and Pasandideh 2020), (Ferrández-Pastor et al. 2019) (Hassan, Ati, and Neima 2021) under Different Irrigation and Cultivation Methods. Journal of Ecological Engineering, 22(10), 192–204. This research applies the Arduino Uno microcontroller (Badran and Obiedat 2022) (Carbajal-Morán, Márquez-Camarena, and Galván-Maldonado 2022) due to simpler implementation (Padyal et al. 2018), availability and cost-effectiveness (Noerhayati, Dwisulo, and Rahmawati 2020).

However, various studies have been conducted (Ferrández-Pastor et al. 2019), (Gultom et al. 2017), (Latif and Megantoro 2020), using Arduino with IoT (YASUBA et al. 2018), (HOSHI et al. 2018) and (Atieh et al. 2018), but few investigations have concerned automated sprinklers, especially in terms of crop yields. Therefore, the aim of this study was to determine the variation of watering model effects (conventional, manual and micro controller-based automatic sprinklers and IoT) on the growth, yield and quality of Pak Choy mustard plants (Brassica chinensis L). An automatic sprinkler system design was developed to provide for the growth of Brassica chinensis L plants. The hypothesis is that this system could match the yields seen from the quality of plants such as chlorophyll and vitamin C from plant. The advantages of this system irrigation compared to manual irrigation are greater practicality because of the use of IoT and water savings.

MATERIALS AND METHODS

This research was conducted in the experimental field of the Engineering Faculty, Malang Islamic University, between April–July, 2020, and involved two primary stages, i.e. developing a device with a programming design, as well as mustard cultivation and laboratory analysis of the plant quality. The tool manufacturing process was divided into three segments, including mechanical, electrical, and programming designs.

Mechanical and hardware design

The mechanical design was composed of a water pump (Shimizu jet pump), 2 water reservoirs, 2 iron torrent poles (3 m high), aw pipes (1, 3/4, and 1/2 inch sizes), 4 sprinkler heads (DN15 type), and 2 stop faucets (3/4 inch).

Electrical design

The electrical design contained ESP8266 NodeMCU v3, soil moisture sensor (YL-69), water flow meter sensor with a size of ½ Inch, servo motor MG996R, 5V 2-channel relay module, and 5V 10A power supply.

Programming design

Arduino IDE and Blynk App are software applications employed in designing the IoT-based sprinkler irrigation system (Todica, 2016).

The mechanical design incorporated two water reservoirs, at a height of 3 meters, and the source is the borehole well. Ultrasonic sensors were installed on the tank and the water level was monitored remotely, using a smartphone (Menna, Remondino, Maas, 2018), (Chen et al. 2020). However, the minimum sensor point was specified at 30 cm, while maximum water height extended to 90 cm. The pump was triggered and shut down automatically at a water level of 30 cm and full capacity, respectively. In sprinkler pipe arrangement, a servo motor controlled by Arduino, is responsible for activating the water faucet to allow convenient water flow (Kamalesh et al. 2018). This nozzle opens automatically in two modes, i.e. 900 or full and 450 or half opening, with subsequent real time adjustment to soil moisture. Four sprinklers were employed between the planting media (mounds/guludan), using DN15 with a gravity-based spray. Moreover, the height of these devices were modified to match the Brassica Chinensis plant at approximately 46 cm, while the distance of each tool was extended to half the planting medium (mounds), at 4 meters. Figure 1 shows the complete designs of the sprinkler system.

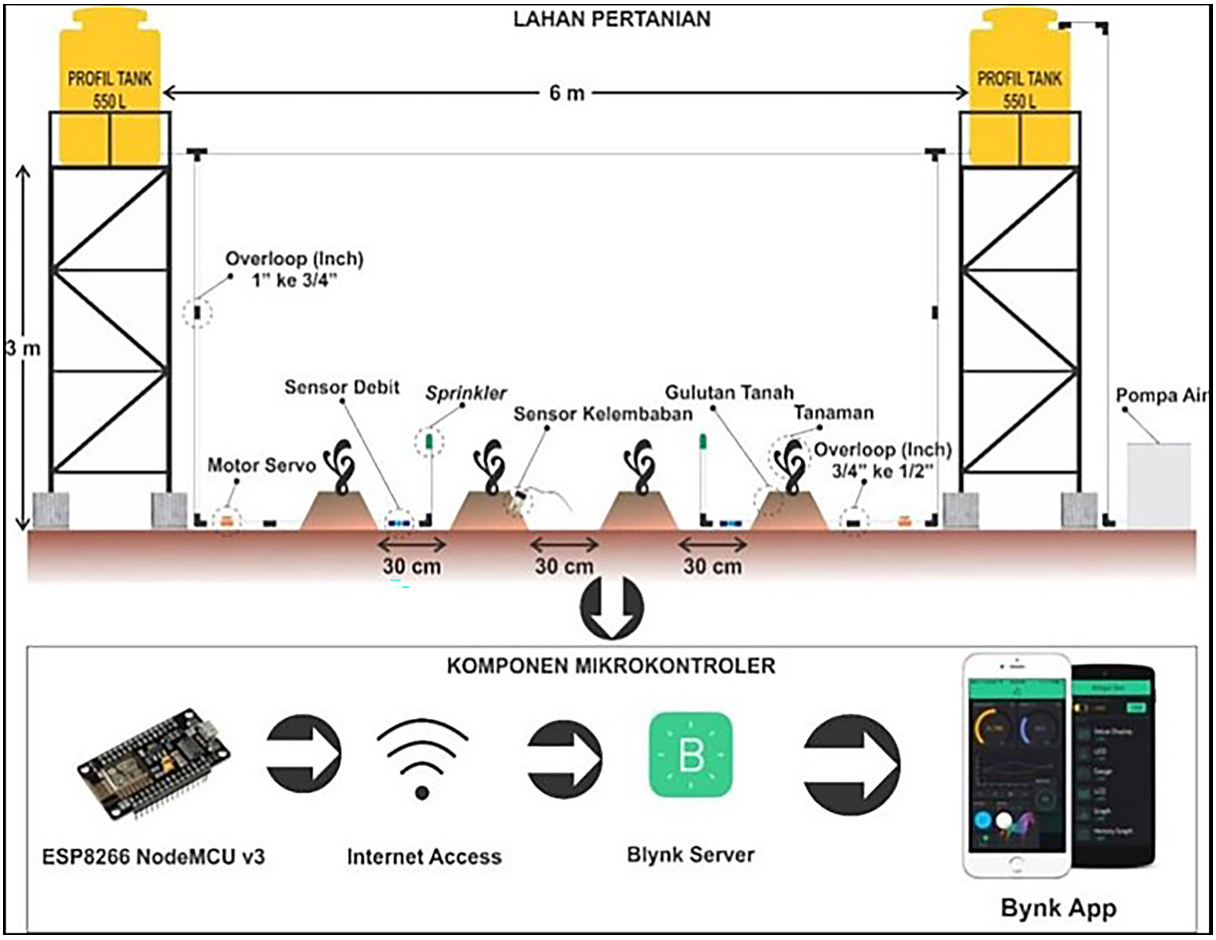

Figure 1. IoT sprinkler irrigation

Cultivation of the Pak Choy mustard plants

The mustard plant cultivation was conducted in various stages, including land processing, seeding and planting, as well as maintenance and harvesting. The land was ploughed by creating mounds of 60 that were wide, 5 m long, and 30 cm high. Prior to planting (14 days), 10 kg compost was applied separately to the soil consecutively placed in minimal polybags, using soil-mixed manure ratio of 1:1. This was followed by perforating a depth of 1 cm to insert the mustard seeds. The Pak Choy mustard seeds were initially selected on the basis of high quality leaves and stems. However, after 2 weeks, the seeds were transferred to the mounds at a dimension of 30 × 30 cm. Daily watering commenced at 6 a.m., using automatic as well as a manual sprinkler and watering can. The automatic alternative incorporates a faucet stop and is connected to a microcontroller, while manual sprinkling is hand-opened. Furthermore, the control was performed with a watering can, consuming about 60 L per treatment or 20 cm decrease in reservoir.

The maintenance processes, including pest and weed controls (Ciaccia et al. 2020) were performed on a 3-day interval by mechanically pulling out weeds or pests, while mustard harvesting was achieved after 42 days of planting.

Plant quality analysis

This study measured certain plant quality variables, including texture, total dissolved solids, total chlorophyll content, carotenoids, and vitamin C.

Texture

The mustard plant texture was evaluated using GY-1 fruit penetrometer (Zhang, Wang, and Cheng 2018), (Yun et al. 2019), and the scale pointer was set to zero for 5 seconds. Subsequently, the leaves were placed under the pointer, with the tip sticking to the fruit, but did not penetrate the peel. However, pressure measurement was attained by holding the start button until the scale terminated at the marker number.

Total dissolved solid (°Brix)

The total dissolved solids was determined using a refractometer (Torres-Sánchez et al. 2020), (De Cillis et al. 2019), by the measurement of 1 g of mustard with a watch glass, addition of 10 drops of distilled water, and the introduction of resulting solution on a refractometer with a dropper, in order to read the values.

Chlorophyll and carotenoids

Chlorophyll and carotenoids were calculated by the absorbance method using a spectrophotometer (Shah, Houborg, and McCabe 2017), (Guberman-Pfeffer and Gascón 2018), (Hernández et al. 2021). The chlorophyll test stages included, carefully weighing 0.5 g of the samples, addition of 10 mL of 100% methanol with a pipette, and then centrifuging at a speed of 4,500 rpm for 10 minutes. Furthermore, the supernatant was filtered with Whatman paper and the absorbance at wavelengths of 470, 652 and 665 were recorded. Meanwhile, chlorophyll (μg / 100 g) determination was attained, by the following equations:

$$\text{Ch-a} = 16.72A665 - 9.16A652 \tag{1}$$

$$\text{Ch-b} = 34.09A652 - 15.28A665 \tag{2}$$

$$Cx{+}c = (1000A470 - 1.63Ca - 104.96Cb)/221 \tag{3}$$

Vitamin C

The vitamin C measurements were conducted by means of the titration method (Prasad, Tran, and Gartia 2019). A 2.5 g sample was crushed to achieve a smooth nature, followed by the addition of 25 mL of distilled water. Consequently, the solution was homogenized by a stirrer for 5 minutes and also filtered. Furthermore, 1 mL phytrate was collected and diluted with 10 mL of distilled water, including a separate 5 mL of the initial sample. Subsequently, 0.1 mL amylum was introduced to the mixture and titrated with 0.01 N iodine. The end point was indicated by a color change to blue tinge.

The resulting data were averaged and further evaluated, using one way analysis of variance, ANOVA [32]. Meanwhile, soil moisture measurement via the gravimetric method, was compared to similar samples, using unpaired t test with a 5% level. Figure 2 provides a simple illustration of the sampling plan.

$$\text{Vitamin C}\left(\frac{\text{mg}}{\text{100g sample}}\right)100 = \frac{\text{(titer (mL) x 0m88 x the dilution factor}}{\text{sample weight (g)}}100 \tag{4}$$

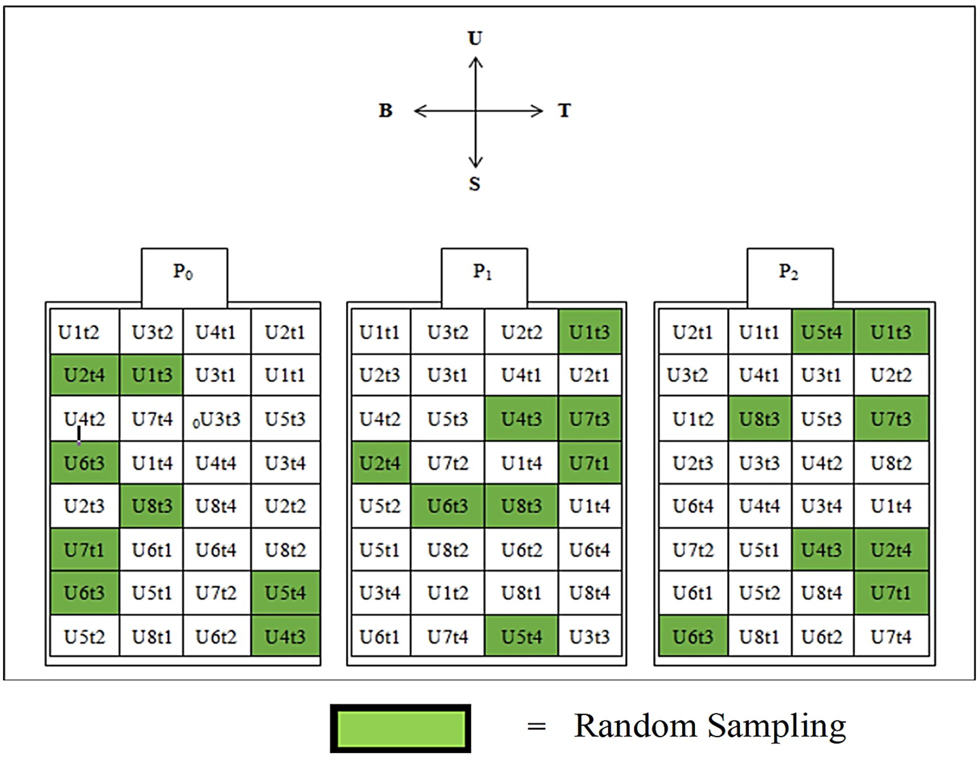

Figure 2. Sampling plan

RESULTS

The results comprises the number of water discharge data, moisture calculations, and the total chlorophyll from 3 treatments, using a watering can = Po, manual sprinkler = P_1, and automatic sprinkler watering = P_2. However, each process was repeated at 8 intervals, containing 4 plants on every stage. Figures 3 and 4 show the observation of the moisture value and water discharge, with the Blynk App, while Table 1 represents the related experimental results of these parameters.

Table 1. The related experimental results of these parameters

No	Soil moisture (%)	Soil moisture condition category
1	10 – 70	Dry
2	30.1 – 70.0	Moist
3	Above 70	Wet

Table 2. Soil Moisture values from observations results

No	Soil moisture (%)	Soil moisture condition category
1	68.5 – 100	Dry
2	29.4 – 68.4	Moist
3	0 – 29.3	Wet

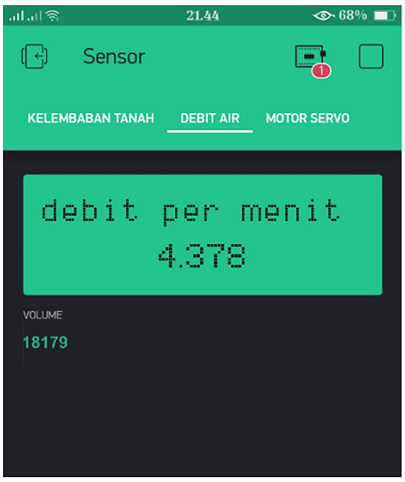

Figure 3. Soil moisture performance for planting mustard greens before and after watering

Table 3. Standar deviation before and after watering

P	Before watering	Standard deviation	After watering	Standard deviation
P1	35.9	1.496069	66.26	1.496069
P2	36.86	3.809068	64.23	3.809068
P3	37.62	1.623063	66.91	1.623063

Soil moisture

The Blynk App showed the soil moisture and water discharge. Moreover, the smartphone monitoring display of the soil moisture sensor described the soil's water content. This clearly indicated the opening and closing rates of the sprinkle faucets. On the basis of the test results, observational data processing was conducted.

Table 1 represents the related experimental results of these parameters. Table 2 and 3 represent the readings of moisture sensor data values ranging from 0–1023 bits. These estimates were subsequently synchronized with the soil moisture values according to the theory described in Table 2.

There was no need to flow water from the sprinkler in the presence of a wet soil, but under moist condition, 50% openings were allowed, although all sprinklers were unsealed in dry soils.

Moisture analysis was performed for 10 consecutive days, prior and after watering as well as at 4 p.m. Figure 3 shows the results for the two treatments, termed the first manual (P1) and automatic (P2) include:

The varying watering methods showed insignificant effect on soil moisture conditions. The soil moisture values ranged between 35.9 ± 1.496-37.62% and 64.23–66.91%, prior and after watering, respectively.

Water discharge

Figure 4 shows the water discharge value from the experiment using automatic sensors and smartphones.

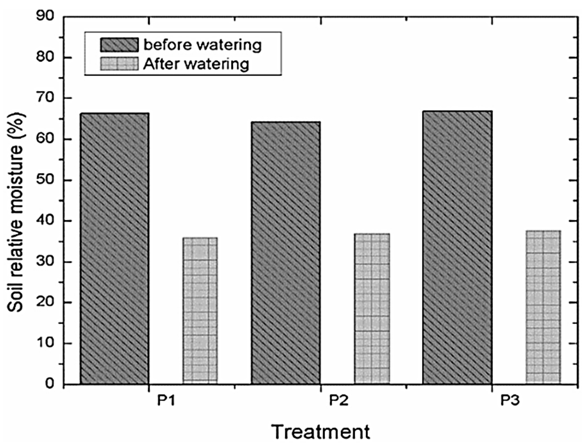

Figure 4 The results of the automatic water discharge value on a smartphone

The discharge data were obtained from volume records and water flow sensors, based on manual calculation analysis. Table 4 indicates the plant quality values of chlorophyll and the manual discharge calculation uses the following equations:

$$Q = V/T \quad (5)$$

where: Q – Discharge (liter / second);
V – volume (liter);
t – time (second).

DISCUSSION

In soil moisture, there is no difference between manual and automatic sprinkler sprinklers. The sprinkler used is able to provide good irrigation whereas the sprinkler used is the DN15 sprinkler model. The DN15 sprinkler is a sprinkler model that can spray water in the form of mist. (Kamienski et al. 2019) stated that a good sprinkler is a sprinkler that is able to provide an even distribution of water during watering.

Plants quality

Figures 5 and 6 recorded no difference between the treatments on plant quality, including total dissolved solids, total chlorophyll, carotenoids, texture values, and mean water content. Chlorophyll refers to the green leaf substance in plants as a photosynthetic pigment (Campbell et al. 2019), (Li and Xiao 2019), while carotenoids are terpenoid compounds or photosynthetic pigments, with color effects ranging from red to yellow (Grassmann 2005). These two materials did not show any significant impact on control, manual and automatic treatments, but were more influenced by sunlight intensity (Loconsole et al. 2019). Furthermore, suggested the light intensity tends to affect the genes responsible for harvest sunlight, therefore causing specie variations. (Suripin (watervoorziening.) 2002)

Plants potentially produce abundant vitamin C (Carr and Vissers 2014), (Netzel and Sultanbawa 2020). In addition, the mineral element functions as an antioxidant to neutralize reactive singlet oxygen (Rey, Zacarías, and Rodrigo 2020), and is only formed by substantial amounts of vegetable and fruits. The Pak Choy mustard plant contains approximately 66.0 mg/100 gr sample of vitamin C. This research demonstrated insignificant results on the vitamin C content in mustard seeds. Diverse methods of water supply tend to generate similar outcomes. Furthermore, the analysis indicated the mustard plant texture did not show

Table 4. Substantial average values from observations result

Treatment	Average of total dissolved solids (°Brix)	Average of total chlorophyll (µg/100 g)	Average of carotenoids (µg/100 g)	Average of Vitamin C (mg/100g)	Average of texture values (N/cm² Pa)
Control (P_0)	3.16	25.22	3.55	53.90	0.84
Manual (P_1)	3.28	21.97	3.12	49.50	0.84
Automatic (P_2)	3.63	17.89	3.52	47.30	0.82
BNT 5%	tn	tn	tn	53.90	tn

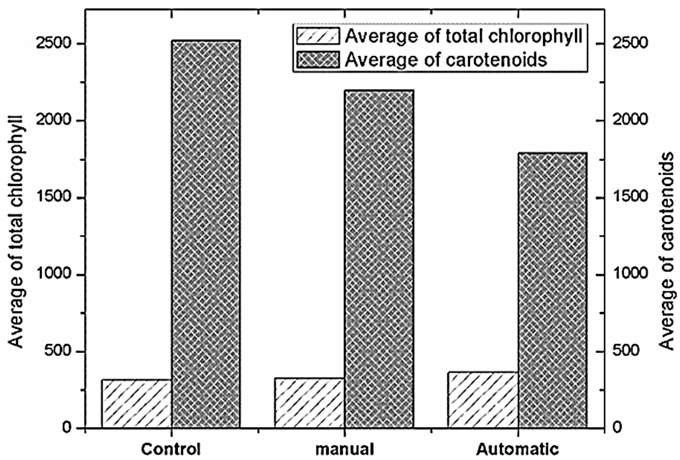

Figure 5. Total chlorophyll and carotenoids of mustard in various watering models

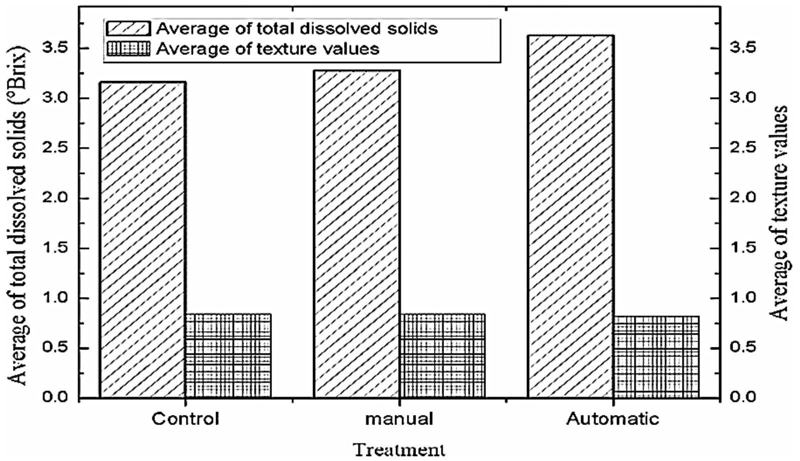

Figure 6. Total dissolved and texture of mustard in various watering models

any important effect on the treatments. However, the texture was influenced by the disintegration of insoluble protopectins into soluble pectins or starch hydrolysis (Trivedi et al. 2015).

CONCLUSIONS

The purpose of this study was to determine the quality of Brassica Chinensis from the chlorophyll and vitamin C results of automatic sprinkler irrigation compared to manual irrigation. After conducting research with three treatments P_0, P_1 and P_3 where P_0 is the conventional treatment of irrigated plants. P_1 is based on automated sprinkler IoT but still controlled by farmers, while P_2 performs watering automatically by a Smart sprinkler system.

The three treatments above mean total dissolved solids under P_1 is 3.16° Brix, P_2 is 3.28° Brix and P_3 is 3.63° Brix. It can be concluded that the quality of plants seen from the average total dissolved solids is not different because the difference is less than 1%. For the amount of chlorophyll, at P_1 is 25.22 µg/100 g, P_2 is 21.97 µg/100 g and P_3 is 17.89 µg/100 g. Judging from this, the difference in the amount of chlorophyll is quite significant, namely around 30%. The amount of chlorophyll is different when there is no control at all from the farmer.

As for carotenoids for treatment 1, P_1 is the magnitude of 3.55 g/100 g, for P_2 is 3.12 g/100 g and P_3 was 3.52 g/100 g. The differences in treatment 2 with manual irrigation by farmers are less than 2%. In turn, the difference with automatic watering even less than 0.1%. It can be concluded for carotenoids, there is no difference in quality results. Quality of vitamin C, for amount of P_1 is 53.90 mg/100 g, P_2 is 49.50 mg/100 g and P_3 is 47.30 mg/100 g. The difference is less than 2% for P_3 and P_2 is less than 1% compared to the P_1.

On the basis of the results and discussion, the sprinkler controlled with IoT-based Arduino, showed a high capacity to generate similar chlorophyll values using conventional sprinklers, including manual settings. However, water preservation was an obvious advantage, due to the existence of soil moisture control in the device.

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