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Development of Hydroponic Root Zone Cooling System for Selected Vegetables (*Lactuca Sativa*) Cultivation Under Crop Protection Structures.

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ABSTRACT

Hydroponics cultivation method commonly applies for growing leafy vegetables and sometimes fruit vegetables. Problems commonly associated with hydroponic system are wastes of growing media and liquid, and water temperature can easily increase under direct sunlight in the tropics region. Thus, this study is conducted to develop cooling system for hydroponic water tank which can control the water-dissolved nutrient temperatures that suits the crop growth needs. This paper highlights the development of hydroponics root zone cooling (HRZC) system and the performance of *Lactuca Sativa* growing under crop protection structure via HRZC system. It was found that the HRZC system was able to distribute and control the hydroponic water-dissolved nutrient temperatures flow to the hydroponic growing container which has a length of 4m long at different height levels of the structure wall. The ranges of temperatures that can be controlled using the HRZC system were between 15 ^{o}C to 25 ^{o}C which meets the crop-root zone temperature needs. The process of chilling and controlling the root zone temperatures to the crop-root requirement seems to have impact on *Lactuca Sativa* growing performance and yield weight where the crop that cultivated via HRZC shows a better growing performance and yields compared to the crop that cultivated via conservative hydroponic method.

KEYWORDS

Hydroponics, Root zone cooling, Crop protection structure.

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INTRODUCTION

Vegetables in Malaysia are commonly cultivated in open field production system, which involves heavy use of inputs and labour (Farahzety et al., 2017). In tropical lowland of Malaysia, heavy rainfall, wind and various plant pests and diseases often damage the open field grown vegetables. Most vegetables are able to grow at temperatures between 20 and 35 ^{0}C, rain range about 600 to 1250 mm/year, humidity at 60-80% and light intensity at 2000-8000 Wm^2 (Rezuwan and Mohammed, 2007). The average temperatures between May and August in tropical country is above 35 ^{o}C and between August and February is below 35 ^{0}C (Julia, 2004). This inconsistent climate condition is not suitable for vegetables growth. Those climate factors can increase the water temperatures inside the hydroponic tank and effects the dissolved nutrient.

Malaysia Agriculture Research and Development Institute (MARDI) had developed several cooling techniques in greenhouse to increase the production of temperate crop in lowland. Research have been done to explore the alternative technology of cooling such as root zone cooling system, misting fan, evaporative pad and ventilation fan which can reduce the production cost (Ahmad Syafik et al, 2010). This root zone cooling system can be adapted to the hydroponics cultivation method which enables the water-dissolved nutrient temperature to be controlled. By manipulating the root zone temperatures with adequate lighting system, it would increase the crop productivity (Gosselin & Trudel, 1984). It was reported that the effect of root zone temperature is greater on root growth especially in early stage of crop development (Mohammud et al., 2012). Studies have shown that crop roots are more sensitive to fluctuation in temperature than crop shoots

However, extreme root zone temperature manipulation can cause excessive vegetative growth, flower abscission and poor fruit set. Thus, it is important to consider the crop requirements before planning for cooling technique (Mat Sharif, 2006). In this study, hydroponic root zone cooling (HRZC) system was developed to cultivate high value vegetables in tropics and to determine the effects of HRZC on crops growth and yields. Among the many varieties of high valuable vegetables in Malaysia, Lettuce of *Lactuca Sativa* varieties have been chosen as selected vegetable in this study due its affordable price in Malaysia markets which is between RM 6/kg and RM 8/kg. Moreover, *Lactuca Sativa* also known and popular because it can be grown easily with the hydroponics system besides having simple maintenance procedure. The objectives of the study were: (1) to evaluate the HRZC system performance in distributing and controlling water-dissolved nutrient temperatures to meet crop-root requirement needs; (2) to study the effects of ambient temperature on HRZC system and conservative hydroponic method under crop protection structure; and (3) to study the effects of hydroponics cultivation method with and without chilling system to the *Lactuca Sativa* growing performance.

MATERIALS AND METHODS

The study was conducted at Engineering Research Centre, Malaysian Agricultural Research and Development Institute (MARDI) in Serdang, Selangor Malaysia with latitude 20 59, N, longitude1010 42, E and 37.8m above sea level (Diyana, 2009).

Hydroponics root zone cooling systems development

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Hydroponics root zone cooling systems development

HRZC was developed by the integration of 1 hp chiller system that can control the water-dissolved nutrient temperature into the hydroponic water tank (Figures 1 and 2). The water-dissolved nutrient will be chilled till 10 ^{0}C and flowed using a 0.5 hp water pump to the hydroponic growing container which was 4m long and vertically arranged at 2m long each level at the wall of the crop protection structure (Figure 1). The water-dissolved nutrient temperature inside the 4m length of hydroponics growing container at different levels will be controlled between 15-25 ^{o}C using a pipe valve and water with velocities between 5-10 m^3/s. The chiller will be on for 12 hours from 7.00 am in the morning till 7.00 pm in the evening.

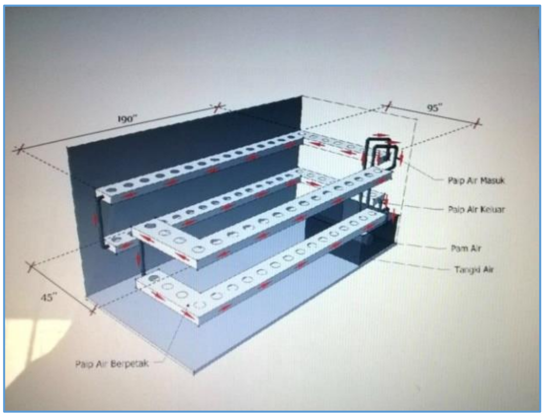

Figure 1: Systems schematic drawing

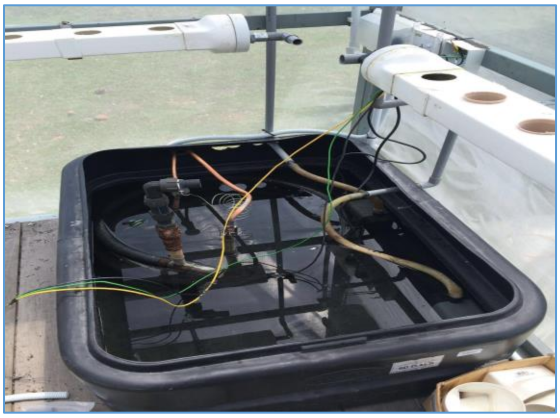

Figure 2: Cooling System

Lactuca Sativa cultivations

Lactuca Sativa were planted in a Nutrient Film Technique (NFT) hydroponics plot of 20 cm wide, 10 cm thick and 4 m long (2m long at each level) that vertically arranged inside a crop protection structure (Figure 3). The water level inside the growing container was 8cm which can reach by the crop roots. The crop spacing was 10 cm, and for 8m long of growing container it can accommodate near 300 crops. *Lactuca Sativa* was transplanted under the crop protection structure after 3 weeks of seeding in nursery. The crops were transplanted and grow inside the structure for 3 weeks (Figure 4) before harvested.

Figure 3: Cultivation inside crop protection Structure

Figure 4: Lactuca Sativa after 2 weeks

Data collection

The data of average water-dissolved nutrient temperature for 10 points i.e. from H1.1 to H1.10 along the growing container (2m long) were collected for 4 weeks; from 2nd April to 23rd April 2017 between 8.00 am and 5.00 pm in order to evaluate the water-dissolved nutrient temperature distribution along the pipe line. The ambient temperature was also collected at the same interval and time to study the correlation between the ambient temperature, conservative hydroponic water- dissolved nutrient temperature without cooling systems and hydroponic water-dissolved nutrient temperature with cooling systems (HRZC). Fifty crops were selected as experiment crops by which 25 of the crops were cultivated using the HRZC system while another 25 were cultivated via conservative hydroponics method. The average data of steam diameter, leaves number, yield weights, crop heights were collected to study the correlation between the crop growing performance and the developed HRZC system.

RESULTS AND DISCUSSIONS:

Hydroponic root zone cooling (HRZC) system performance

Average water- dissolved nutrient temperature distribution profile of HRZC system for 4 weeks from 8.00 am to 5.00 pm daily at different 10 points and levels were illustrated in Figure 5. Based on the graph, there was no significant difference between 10 points data along 4m of hydroponics growing container at different levels. In average, the HRZC system was found to be able to maintain the root zone temperature at different length and height of hydroponics growing container. The minimum water-dissolved nutrient temperature was 12.33 °C at 10.00 am, located at the early entrance of the flowing water from the water tank at 4 points which were H1.1, H1.2, H1.3, and H1.4. The heat loss was very minimum at these points due to length, water velocity, water level and ambient temperature factors. The maximum water-dissolved nutrient temperature was 23.5 °C at 3.00 pm, located at points H1.7 and H1.8. This was due to that points were located at the end of the growing container which having accumulated heat loss along the pipe length. Moreover, at 3.00 pm, ambient temperature was at the maximum conditions which can increase the heat loss of water-dissolved-nutrient temperature that flows inside the growing container.

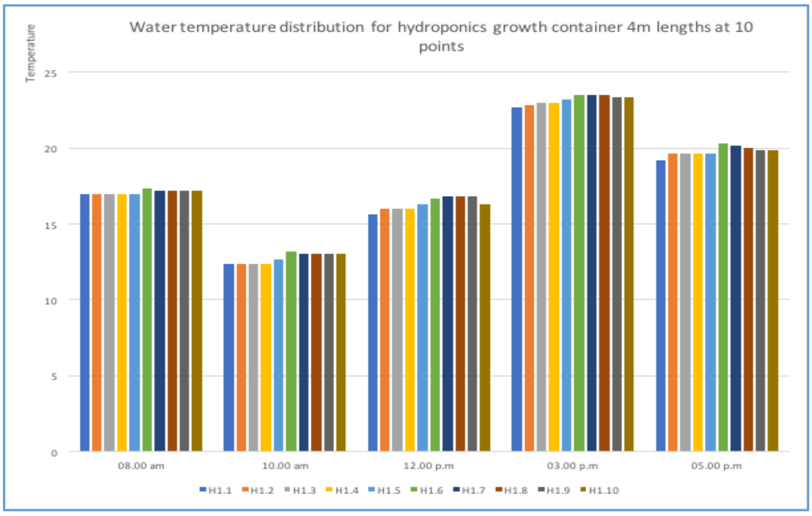

Figure 5: Average water-nutrient temperature distribution profile of HRZC

Ambient temperatures effects on HRZC system.

The change of average ambient temperature data from 2 April to 23 April 2017 is as shown in Figure 6. From the graph, R^2 value is being equal to 0.707 which shows moderate to strong correlation between the ambient temperatures and water-dissolved nutrient temperatures for conservative hydroponic method. The maximum value and minimum value for ambient temperature was 32.5 °C and 30.21 °C., respectively. The maximum value and minimum value for conservative hydroponics water-dissolved nutrient temperature was 29.32 °C and 28.89 °C. respectively.

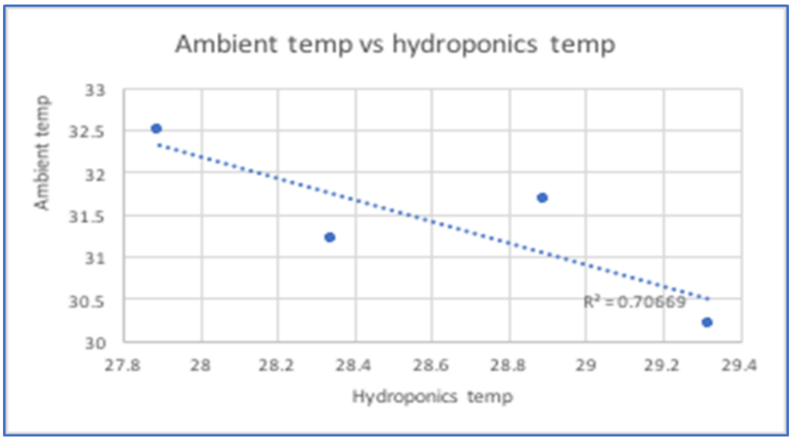

Figure 6: Ambient temperature vs hydroponic temperature

Figure 7 shows the effect of ambient temperatures on HRZC system. From the graph, R^2 value is 0.892 which shows strong correlation between the ambient temperatures and water-dissolved nutrient temperatures of HRZC system. For HRZC water-dissolved nutrient, its maximum temperature was.23 °C while its minimum value was 17.34 °C. From the analysis, it shows that the ambient temperatures have more effects on the HRZC compared to the conservative hydroponics method. The findings were in agreement with Mohammud et al, (2012) who integrated the root zone cooling system with conventional control system inside the greenhouse for tomato cultivation in lowland areas. The system was not just able to meet a soil-root temperature requirement but also reduced the environment temperature and increased the environment relative humidity.

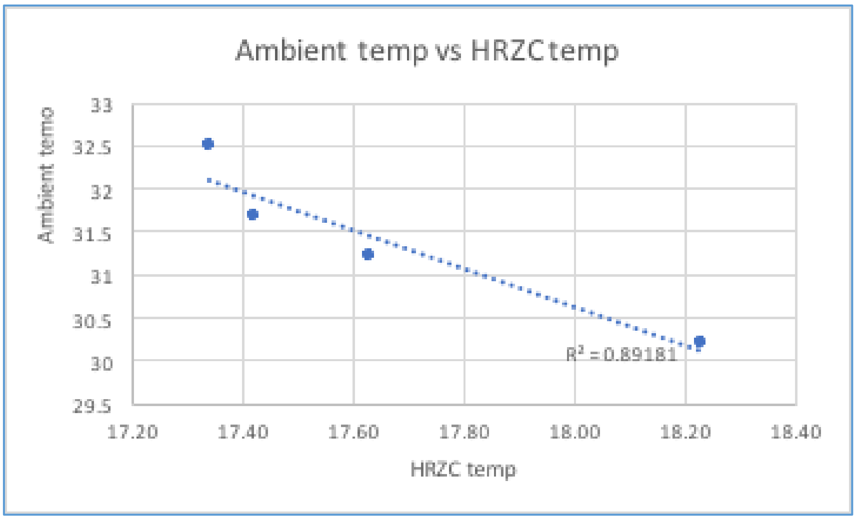

Figure 7: Ambient temperature vs HRZC water-nutrient temperature

Hydroponics root zone cooling effects on *Lactuca Sativa* growing performance

Data in table 1 shows the results obtained for all *Lactuca Sativa* growing performance parameters such as leaves diameter, heights, leaves number and yield weights cultivated via conservative hydroponics method and HRZC system for 3 weeks from 2nd April 2017 to 23th April 2017. From the table, it was found that the leaves diameter, leaves number and yields weight for the crop cultivated via HRZC showed better performance than the conservative system. However, for crop height performance, the crop cultivated via conservative hydroponic method showed better performance than HRZC. This could be due to the *Lactuca Sativa* growing performance is not presented by the height increment but the weight of the leaves. The table also indicated that from week 1 to week 2 after the crops transplanted to the system, the crops growing performance showed significant changes and fast increment for both treatments.

Table 1: *Lactuca Sativa* growing performance using hydroponics and HRZC

	Leaves diameter (mm)		heights (mm)		leave numbers		Yield weights (g)	
Date	Hydroponics	HRZC	Hydroponics	HRZC	Hydroponics	HRZC	Hydroponics	HRZC
02/04/2017	17.29	16.75	5.52	5.59	6.39	6.22	54.67	58.67
09/04/2017	52.45	56.26	9.13	10.20	7.96	8.17		
16/04/2017	89	100.07	11.85	12.77	10.68	10.81		
23/04/2017	115.2	122.38	15.07	14.68	14.09	14.27		

Hydroponics root zone cooling effects on *Lactuca Sativa* leaves diameters

Leaves width represents the growth of the crops where respiration, transpiration and photosynthesis take place. *Lactuca sativa* diameters were measured from end to end of the leaves. Figure 8 shows *Lactuca Sativa* leaves diameter cultivated via conservative hydroponic method and HRZC system. The graph shows the crop cultivated using HRZC system obtained faster growing performance compared to conservative hydroponic method. The leaves diameter growing performance for both treatment have a strong correlation with the cultivation methods with R^2 value of conservative hydroponic method is 0.995 and for HRZC is 0.984. The maximum leaves diameter for crops cultivated via HRZC and conservative hydroponic method after 3 weeks being transplanted into the growing containerwere 122.38 mm and 115.2 mm respectively. There were significant different in the change of leaves diameter of *Lactuca Sativa* cultivated via conservative hydroponic method and HRZC where HRZC system obtained faster leaves diameter growing performance.

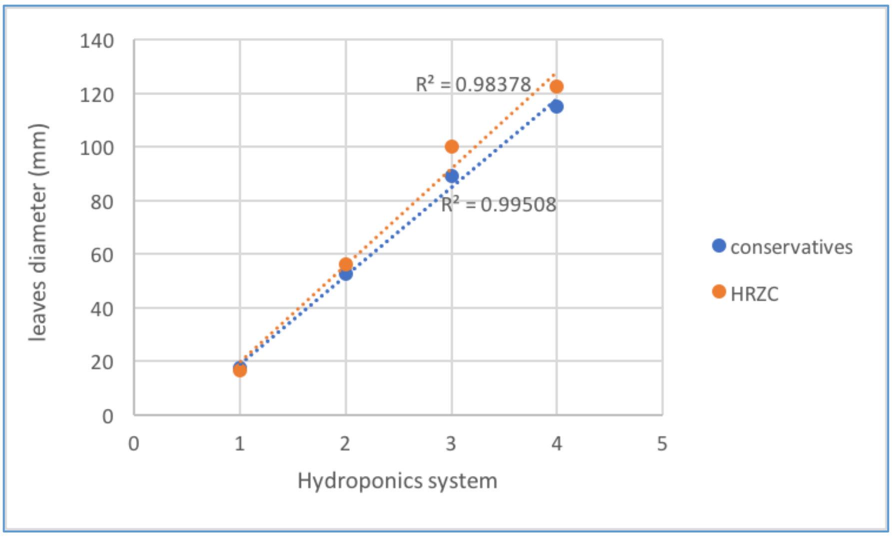

Figure 8: Lactuca Sativa leaves diameter cultivated via hydroponics and HRZC

Hydroponics root zone cooling effects on *Lactuca Sativa* heigths

The *Lactuca Sativa* height is important to represent crops growing performance. The ability to receive light intensity and fight for spaces between the crops is important for the crops to increase growth (Syafik et al, 2010). Figure 9 shows the *Lactuca Sativa* heights cultivated via conservative hydroponic method and HRZC system. For both treatments, crop height increased weekly and the height for crops grown with HRZC seems to increase faster than the conservative hydroponic method from week 1 to week 3. However, the maximum height of the crops cultivated via HRZC system and conservative hydroponic method four weeks after being transplanted were 14.68 mm and 15.07 mm respectively. From the study, it shows that the crop cultivated via HRZC have better leaves weight (Figure 9) and this is the reason why crops cultivated via HRZC system were shorter than conservative hydroponic method at the end of the season. The leaves diameter growing performance for both treatment have a strong correlation with the cultivation methods with R^2 value of conservative hydroponic method is 0.997 and for HRZC is 0.956. The data showed no significant different between plant height cultivated without and with the chilling system.

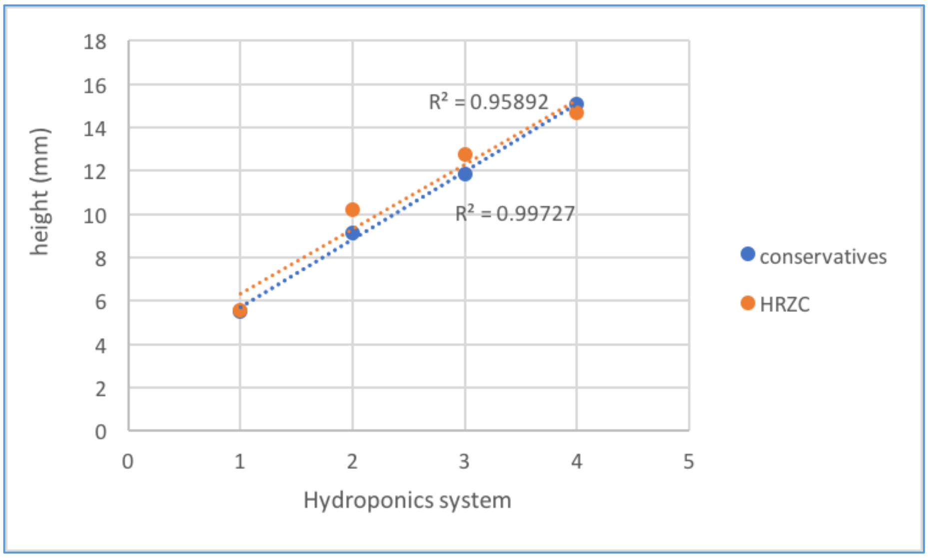

Figure 9: Lactuca Sativa heights cultivated via hydroponics and HRZC

Hydroponics root zone cooling effects on *Lactuca Sativa* yield weight

Figure 10 represents *Lactuca Sativa* yields weight cultivated via conservative hydroponic method and HRZC system. Basically, weight is important parameter as the price in the market depends on the weight of the crop. The yield for the crops cultivated using HRZC system and conservative hydroponics method had a maximum average weight of 58.67 g and 54.67 g respectively. This shows that both of the cultivation methods have a significant different yield and HRZC system can produce better quality yields compared to conservative hydroponic method.

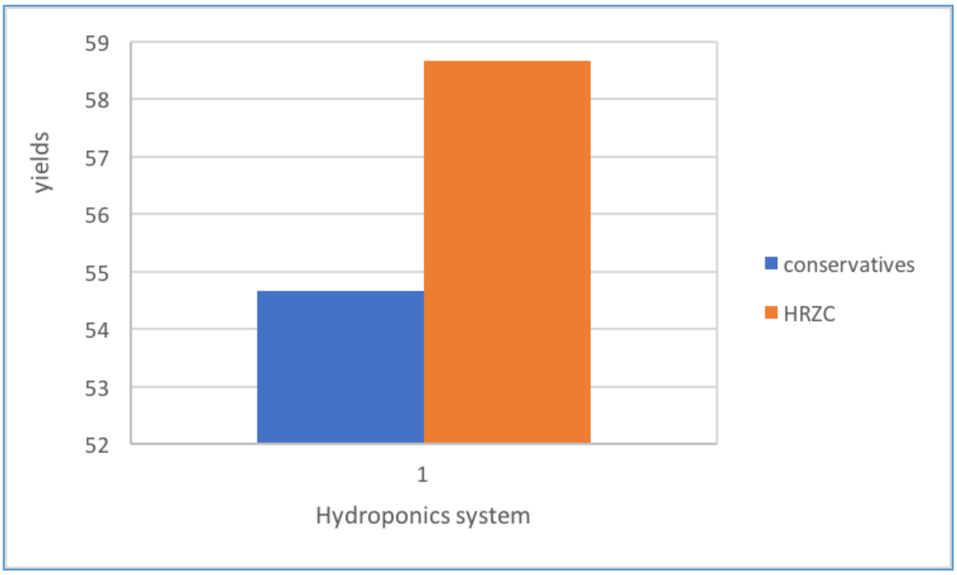

Figure 10: Lactuca Sativa yields cultivated via hydroponics and HRZC

CONCLUSIONS

As a conclusion, it was found that the HRZC system was able to distribute and control the hydroponic water-dissolved nutrient temperatures flow to the hydroponic growing container at different height levels of crop protection structure wall. The ranges of temperatures that could be controlled using the HRZC system were between 15 ^{o}C to 25 ^{o}C which meets the crop-root zone temperature needs. The ambient temperatures gives effect to the water-dissolved nutrient temperatures, in which the increase of ambient temperature can increase the water-dissolved nutrient temperatures inside both of the hydroponic cultivation methods.

Lactuca Sativa growing performance and yield weight was found to be better using the HRZC systems. The leaves diameter of the crops cultivated using the HRZC system was found to increase faster week by week as compared to the crops cultivated via conservative hydroponic method. The crop height also increased faster using the HRZC system compared to the conservative hydroponic method. The chilled water can increase the growing performance of the crops are shown by crop height in finding light to process the photosynthesis. The process of chilling and controlling the root zone temperatures to the crop-root requirement seems to have impact on *Lactuca Sativa* growing performance and yield weight.

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