Development of a portable model of heat treatment tent with bottom black cover for the control of citrus greening disease in Brunei

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Abstract: Citrus Greening Disease is a serious bacterial disease in citrus plants which causes loss of production of citrus fruits all over the world, including Brunei. A portable and thermal effective heat treatment tent was developed as an attempt to control and manage this disease. A 1.4 m tall tent with opaque canvas was fabricated to test for a 1.2 m tall lime tree. The testing involved heat treatment tests for three days with tent having black plastic sheet bottom cover and without bottom cover over the soil surface around the plant. Overall, the results proved that the plant was not damaged during the heat treatment, and the fabricated tent frame was light and portable with minor folding and stability problems. The tent was unable to maintain the desired temperature 38°C - 42°C for more than 5 hours due to the sun position and changing weather conditions, but the heat treatment test with tent having bottom black colour plastic sheet was able to maintain the temperature of the bottom part of the plant more effectively. Hence, the tent can be used in agricultural sites at full scale to treat the infected plants in Brunei environment and the cost of the tent is approximately BN$100 at the present market price.

Keywords: heat therapy, tent, citrus, greening disease

Citation: Basunia, M. A., and M. Syazmuie Bin Haji Sufri. 2020. Development of a portable model of heat treatment tent with bottom black cover for the control of citrus greening disease in Brunei. Agricultural Engineering International: CIGR Journal, 22(1): 100-107.

1 Introduction

Citrus Greening Disease, famously known as Huanglongbin (HLB) is a serious bacterial infection affecting citrus plants all over the world. HLB is caused by a type of bacterium, *Candidatus* Liberibacter Asiaticus, or simply known as Las Bacteria, which is spread by an infected Asian citrus psyllid (McCollum and Baldwin, 2016). A citrus plant which is infected with HLB produces low quality and bitter fruits; and the tree will eventually die within three to five years if no treatment is applied. Once a tree is infected, there is no cure. This resulted in huge loss of citrus production and declination of the economic value of citrus fruits globally (French et al., 2001; Reza and Pertiwi, 2015). There is no cure for HLB in infected trees but prevention and control of the spread of bacteria can be attained through heat treatment (Ehsani et al., 2013; O'Brien and Duan, 2013). Raising the temperature of infected-trees (heat treatment) could be a promising technique to control the HLB. Heat treatment (thermotherapy) has been used for plant disease control for a long time. However, most of these attempts were conducted

Received date: 2019-06-10 **Accepted date:** 2019-12-19

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under controlled environment in the laboratory. In a controlled-growth chamber, Hoffman et al. (2013) exposed citrus seedlings infected with HLB to different heat treatments for a duration of 2-120 days. The results indicated a reduction in the level of HLB bacteria within the treated seedlings as compared with untreated ones. Based on their results, exposing the seedlings to 40°C -42°C continuously for a minimum of 48 hours eliminated or significantly reduced the HLB bacteria in the treated citrus seedlings. The treatment involves placing an infected plant under an enclosed space, where the temperature inside is raised to a high temperature using solar energy in order to eliminate the existing pathogens and to slow down the spread of disease inside the plant (O'Brien and Duan, 2013). This method of heat treatment method as it only requires little investment and it is very easy to set up. The process only involves utilizing solar energy from the sun to raise the temperature inside the tent in order to denature the Las bacteria in the plant and killing them (Mark, 2017). The temperature inside the tent depend on the surrounding temperature and the amount of solar energy radiating the tent. A similar but unique heat treatment tent experiment had been done by the Agricultural Research Service (ARS), U.S. Horticultural Research Laboratory (USDA, 2013). The infected trees were enclosed in opaque polyvinyl chloride (PVC) tents and were left to heat up for a week. Then the top part of the tree, which was browned due to the effect of solar heat, was removed. The results showed that the disease is toning down and the productivity of tree had recovered. In another experiment, a heat treatment tent made up of PVC frame and opaque plastic canvas was carefully set up to ensure the top side of the tent is near to the topside of the infected tree to maintain heat at the top part of the tree. Cinder blocks were to used hold the tent stable in position. At noon, the temperature inside the tent have reached 47^{o}C at the top part and around 43^{o}C near the bottom of the tree. After completing the treatment, the tent can be reused and transferred easily to another tree which was claimed to be cost efficient and effective (Reza and Pertiwi, 2015; Mark, 2017). The studies and reviews above are more focused towards building a portable and thermally effective tent. PVC is the most selected material for the tent frame as it is cheap, lightweight and the same time durable. For the tent canvas, an opaque polyethylene is recommended to avoid excessive heating which could kill the leave tissues. Hence, to design and create a foldable type and more thermal effective in eliminating the pathogens without having negative impacts on the leaves is desirable solution for heat treatment tent. The objective of this project focused more on improving the design and effectiveness of the heat treatment tent. The aim was to fabricate a portable and retractable heat treatment tent that could be transferred from one plant to another easily. At the same time, the tent must undertake some alterations in order to maintain the temperature between 35°C to 42°C during day time by only utilizing solar energy. Successfully maintaining the required temperature for at least 48 hours with certain interval will eliminate the pathogens without causing damage or killing the tree. A heat treatment tent was successfully design fabricated and thermal performance was studied (Basunia and Simaa, 2018) to control this in Brunei environment. The material choice for the frame of the tent was steel, which was too heavy and hardly portable to transfer it from one plant to another. Another issue was that the heat treatment experiment resulted in the browning of the leaves at the top part of the plant due to excessive heat inside the tent. Hence, further improvements were required on the tent to develop a more portable and more thermal effective tent. The fabrication was involved only building a prototype model of the heat treatment tent, which was an estimation of a full scale tent.

2 Materials and methods

A 1.4 meter uninfected and healthy lime tree was used for the heat treatment test. The tree was trimmed carefully to fit exactly inside the tent for efficient heating when subjected to heat inside the tent by solar energy from the sun, and the condition was continuously monitored until the desired result was obtained. The material and dimension of canvas for the enclosure of infected plant are crucial as thermal conductivity and resistance rely on both factors for thermal effectiveness. An opaque polyethylene canvas was selected to minimize the effect of leaf burns. The canvas was reused from an old car cover which was made of polyethylene material. The detail for the canvas used in this experiment is shown in Table 1.

Table 1 Dimension and properties of tent canvas

Item	Location	Thickness (mm)	Width (mm)	Height (mm)
Canvas	Top	0.1524	600	600
	Side	0.1524	600	1400

The tent frame was lightweight in order to allow it easily and quickly transferred to another tree. This required minimum number of linkages for the ease of assembly and disassembly, but the structure was strong enough to withstand the weight of canvas and the external environment. PVC was selected as the most suitable material for the tent frame as it is lightweight and rigid. The stability of PVC was reinforced by bricks to hold the tent in place. The full specification of the tent frame is as shown in Table 2.

Table 2 Dimension and properties of tent frame

Item	Material	Width (mm)	Height(mm)
Frame	PVC	600	1400

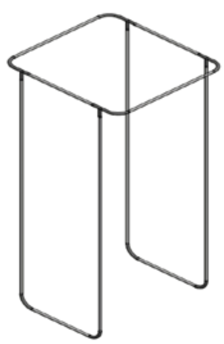

Figure 1 Final tent design drawing

After obtaining the suitable dimension and required criteria for the tent frame, five concept sketches of the frame were produced manually by hand. These sketches were evaluated using Pugh Matrix of concept evaluation. The concept which scored the highest overall weightage mark was selected for optimization to proceed in the testing phase. Optimization involved adding detail drawings and specification using Inventor software. After optimization of the chosen concept, the final drawing of the tent frame for the fabrication stage is as shown in Figure 1.

The protruding part of the frame could be detached to allow the tent to be folded and transported easily. PVC (Polyvinyl chloride) pipes were cut into six 0.6 m pipes and four 1.4 m pipes using a handsaw. The pipes were connected using the appropriate PVC fittings and further secured using the PVC glue. For the detachable joint, PTFE (Polytetrafluoroethylene) film tape was wrapped around the end of one PVC pipe to increase the thickness of the pipe to form tighter fitting connection. This was to allow detachment at one end and one plane rotation at the other end for folding purpose. Then, the canvas was cut into the required dimension to fit at the different sections of the tent. The canvas was secured to the frame using specialized glue and the final heat treatment tent is shown in Figure 2. Small gaps were intentionally made to allow flow of external air in order to avoid overheating of plant inside the tent. Small holes were also made at the top surface to allow rain water to enter the tent.

Figure 2 Final heat treatment tent

After the completion of the fabrication stage, the tent was put to test for the assessment of its thermal effectiveness, performance, durability and portability in real environment. The performance and portability of the tent were tested during the set up for the heat treatment test and dismantling of the tent after the test. For the heat treatment, two tests were performed to determine the thermal effectiveness.

2.1 Heat treatment test without black bottom cover over the surface of the soil around the plant

The tree was enclosed by the tent early in the morning as early as 06:00 hours and was left to heat under the hot sun for 10 hours. Every hour, starting from 07:00 hours the ambient temperature, the temperature inside the tent for the top and bottom part, were recorded. This test was performed for three consecutive days and the leaves of the tree at the top and bottom were examined afterwards.

2.2 Heat treatment test with bottom cover over the surface of the soil around the treated plant

This experiment was similar to that of the previous experiment, but with the introduction of black polyethylene trash bag as shown in Figure 3, to act as a bottom cover of the tent to absorb heat for maintaining and sustaining uniform temperature at the bottom of the plant. The same data collection and examination procedures were performed.

Figure 3 Bottom part of the plant covered by black polyethylene bag

3 Result and discussion

From analysis of the temperature profiles against time (Figures 4-6), the desired temperature which were fatal for Las Bacteria, were reached between 11:00 – 16:00 hours at the Brunei environmental conditions. This time range occurred when sun was in the right position to heat the tent for the treatment process. This indicates that the tent was capable of performing its function for five hours only during the day. The temperature inside the tent were higher than the ambient temperature due to the accumulated heat trapped inside the tent which caused the interior temperature to rise higher. The temperature at top part of the tent was higher as the sunlight directly hit the top part first before the heat was distributed towards the bottom. Hence, the temperature at the bottom was slightly lower. Figures 4-6 display the graphs for the heat treatment test without bottom cover. The temperature at the top of the tent were observed to be consistently higher than the bottom temperature throughout the heat treatment, while the temperature at the bottom of the tent remained between the top temperature and ambient temperature lines. It is clear from the figures 4-6 that the temperature inside the tent can be easily raised to the desired temperature 38-42 ^{0}C, particularly during 11:00 to 16:00 hours. The ambient temperature directly affected the temperature inside the tent as observed from the graph. This is due to the temperature inside adapting to the temperature changes in the surrounding faster due to the lack of insulation between the interior of the tent and the environment.

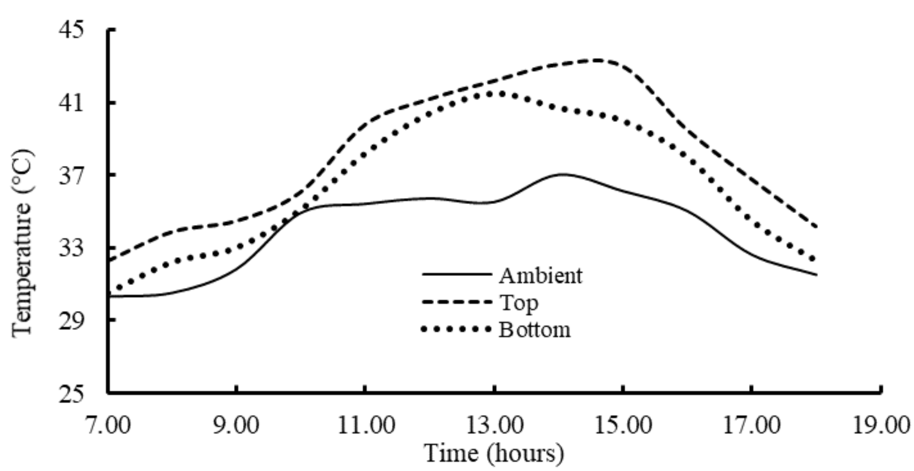

Figure 4 Graph for the heat treatment results without bottom cover for day 1, April 23, 2018

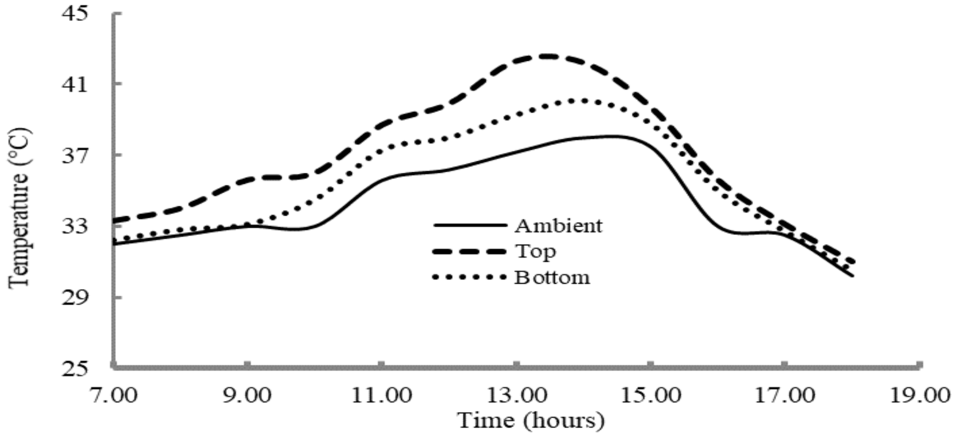

Figure 5 Graph for the heat treatment results without bottom cover for day 2, April, 24, 2018

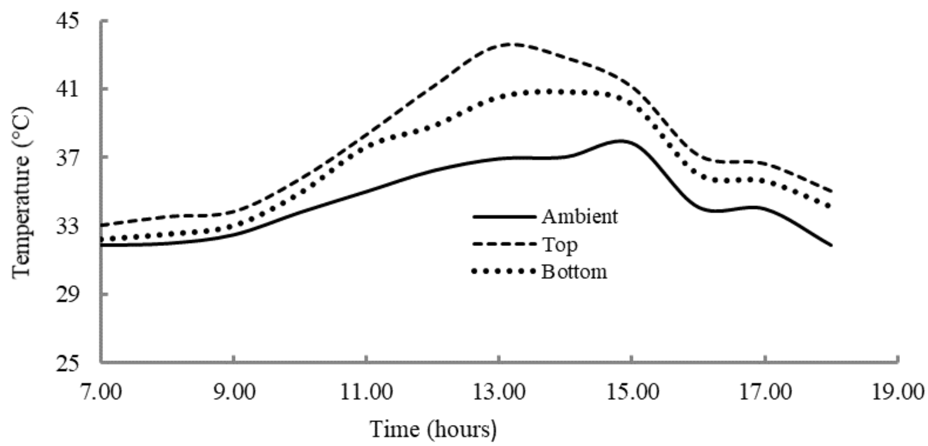

Figure 6 Graph for the heat treatment results without bottom cover for day 3, April 25, 2018

Figures 7-9 display the graphs for the heat treatment test with bottom black plastic cover. The temperature patterns were almost similar to that of the other test, but a few significances were observed at the temperature lines from 12:00 hour onwards. The temperature inside the tent was maintained at high temperature despite the dropping ambient temperatures at a large offset.

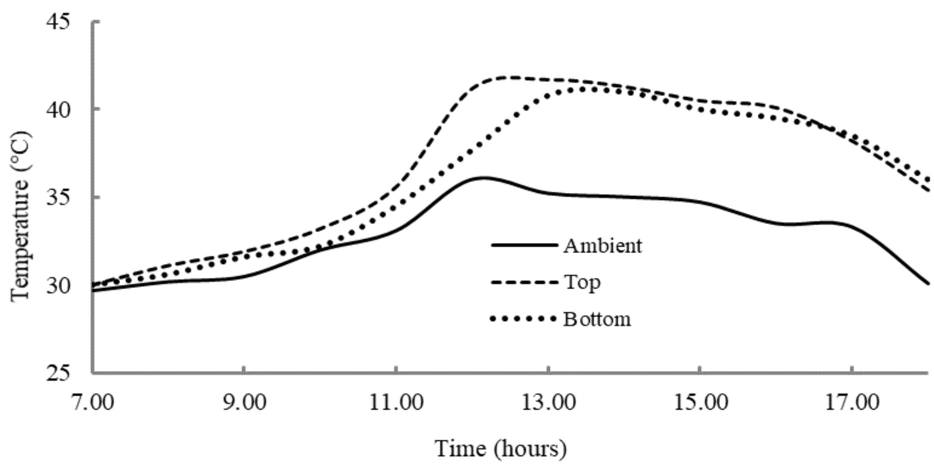

Figure 7 Graph for the heat treatment results with bottom cover for day 1, April 26, 2018

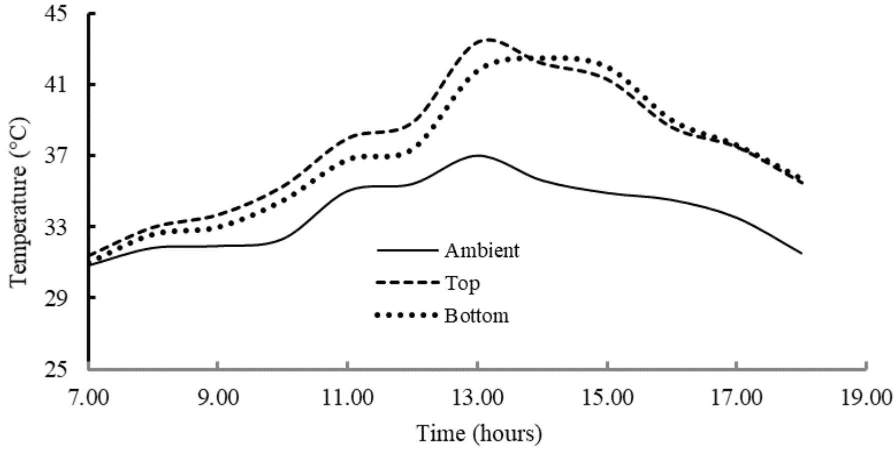

Figure 8 Graph for the heat treatment results with bottom cover for day 2, April, 27, 2018

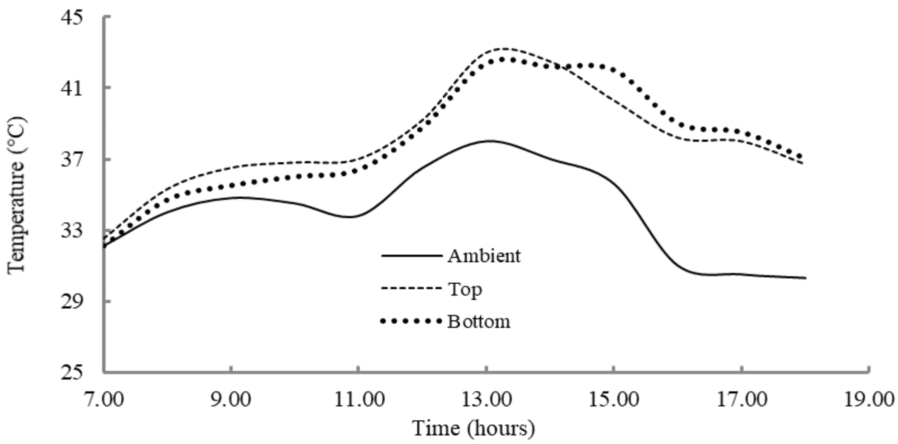

Figure 9 Graph for the heat treatment results with bottom cover for day 3, April 28, 2018

The three days average ambient temperature with bottom covered with black plastic sheet during 11:00 AM 17:00 PM was 35^{o}C and the tent inside temperature was 40.5^{o}C (Figures 7-9). It indicated that the tent was able to maintain above 40.0^{o}C each day for more than 5 hours. It is also proved that if the tent is used continuously for 7-8 days it could drastically reduce a reduction in the level of HLB bacteria as found in earlier research (O'Brien and Duan, 2013). Based on the results (O'Brien and Duan, 2013) exposing the seedlings to 40°C -42°C for a minimum of 48 hours within a week could eliminated or significantly reduced the HLB bacteria in the treated citrus seedlings. The treatment involves placing an infected plant under an enclosed space, where the temperature inside are raised to a high temperature using solar energy in order to eliminate the existing pathogens and to slow down the spread of disease inside the plant (O'Brien and Duan, 2013).

The HLB bacteria cannot be totally eliminated but its breeding capacity can be drastically reduced by natural heat treatment with damaging the environment. Once a tree is infected, there is no cure. This resulted in huge loss of citrus production and declination of the economic value of citrus fruits globally (French et al., 2001; Reza and Pertiwi, 2015). There is no cure for HLB in infected trees but prevention and control of the spread of bacteria can be attained through heat treatment (Ehsani et al., 2013; O'Brien and Duan, 2013)

The bottom temperature of the tent was also consistent with the top temperature and occasionally, was higher than the top temperature. This indicates that the black cover at the bottom of the tent helped to absorb the heat during peak temperature and distributed the heat inside the tent effectively. The ambient temperature was affected by the intensity of heat from the sun and the position of the sun as well. Other factors such as wind current and heat radiation of reflection of the soil were disregarded. These factors are naturally occurring and there are not many ways to control the ambient temperature within the vicinity of the tent placement. The leaves from the top part of the tree faded after the experiment as this part received the most heat and sunlight during the day. However, there was no evidence of tissue damage on the leaves after the heat treatment as there was no visible sign of dying leaves from the tree. On the other hand, the leaves from the bottom part of the tree were still green and healthy which were similar to the leaves before the experiment. The fabricated tent was lightweight and can be transferred from one plant to another easily. The structure of the frame made it easy to set up and dismantle by only one person. However, due to its lightweight, the tent became unstable especially during rough weather condition. Hence, bricks were used as an external load to offer more stability to the tent. Another problem was that the tent canvas folded untidily when the tent was folded. This is due to the lack of support frame for the canvas to retract simultaneously when the tent frame was folded.

The small gaps at the top of the tent act as ventilation to help circulating cool air in order to avoid overheating of the leaves of the plant and thus, prevent damages to the leaf tissues. However, despite the opaque canvas, the sunlight was still able to penetrate inside the tent which mainly affected the leaves at the top side. This resulted in the dry and fading colour of the leaves at the end of the experiment. Overall, the tent was able to keep the plant healthy and trap heat effectively at the same time.

The construction of the tent is simple and costing about BN$ 100.0 at the present market price. The transparent cover sheets of the tent and the bottom covering black plastic sheet of the tent keeping the plant at the center needs to change every year otherwise the frame could last 5-10 years.

4 Conclusion

The heat treatment tent was able to perform effectively in maintaining the desired temperature for five hours only during day time as this method depends heavily on the heat of the sun and the condition of the weather. The tent was also able to prevent tissue damage on the plant leaves, but the colour of the leaves at the top part had faded. The portability for the tent prototype was satisfactory due to its lightweight characteristics but the foldabilty required a few adjustments to ensure that the tent frame and the canvas are properly folded to preserve its integrity and for convenience. The lightweight factor also caused the tent to be unstable during rough conditions, at which external loads were used to maintain the stability throughout the experiment. Overall, the design and performance of this tent have improved from the previous work. The thermal performance of the tent was limited by the ambient temperature and weather in the absence of supplementary heat, but the portability can be further improved through a series of adjustments and alteration to the tent frame and canvas. In conclusion, this heat treatment tent method is an advantage in Brunei due to the hot weather. The prototype model can be expanded into a full scale tent for application in agricultural sites, particularly citrus plants. A few adjustments on the tent and the use of supplementary heat could further improve the performance and portability of the tent. This will help to control and manage the citrus greening disease problem in Brunei at a large scale.

Acknowledgement

The authors are very grateful to the UTB (Universiti Teknologi Brunei) authorities for the financial support to carry out this study.

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