



UNIVERSITI PUTRA MALAYSIA

***MONITORING SOIL PROPERTIES OF INOCULATED AND
UNINOCULATED BASAL STEM ROT (BSR) IN OIL PALM SEEDLING***

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**BACHELOR OF ENGINEERING
(AGRICULTURAL AND BIOSYSTEMS)**

**FACULTY OF ENGINEERING
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Approval Sheet

This project report attached here to, entitled “Monitoring Soil Properties of Inoculated and Uninoculated Basal Stem Rot (BSR) in Oil Palm Seedling” prepared and submitted by NURUL NASYITAH BINTI MOHD KHALIL in partial fulfilment of the requirement for the degree of Bachelor of Engineering (Agricultural and Biosystems) is hereby accepted.

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Abstract

Basal stem rot (BSR) is a serious disease of oil palm in Malaysia. It can cause damage to the root, and later cause restriction of water and nutrients supply to the aerial parts which later causes the palm to die. This study was carried out to monitor the three soil properties, namely soil moisture, electrical-conductivity (EC) and temperature taken from an inoculated and un-inoculated samples of BSR in oil palm seedling. MEC10 sensor is a sensor used in this study because it can give reading of moisture content, EC and temperature. Before it is used, laboratory work was done to see the trend of these three parameters by comparing with other equipment. This study was later conducted in a transgenic greenhouse at Institute of Plantation Studies (IKP), UPM Serdang, Selangor. Oil palm germinated seed at age 5 months were used for inoculation by using rubber wood block (RWB) method. The data collected from MEC10 sensor were taken hourly through an online system. In order to identify how fast the changes can be seen, the analysis has been done at week 3, week 7 and week 12 after plant. The results showed that samples with un-inoculated seedling gave higher reading on moisture content, electrical-conductivity and temperature compared to inoculated. Based on T-test result, soil moisture and temperature gave consistent significant different at all these weeks at 6am, 8am and 8pm; and 1-2am, 4am-2pm and 6pm and 8pm, respectively. In conclusion, the BSR in oil palm seedling can be detected as early as in week 3 after plant using moisture content and temperature value of soil.

Abstrak

Basal stem rot (BSR), adalah penyakit serius kelapa sawit di Malaysia. Ia boleh menyebabkan kerosakan pada akar, dan kemudian menyebabkan pembatasan bekalan air dan nutrien ke bahagian penting yang kemudian menyebabkan akarnya mati. Kajian ini dijalankan untuk memantau ketiga-tiga sifat tanah iaitu kelembapan tanah, konduktiviti elektrod (EC) dan suhu yang diambil dari sampel yang terkesan dari BSR dan tidak. Sensor MEC10 adalah sensor yang digunakan dalam kajian ini kerana ia dapat memberikan bacaan kandungan lembapan, EC dan suhu. Sebelum digunakan, kerja makmal dilakukan untuk melihat perbandingan trend tiga parameter yang diukur menggunakan peralatan lain. Kajian ini kemudiannya dijalankan di rumah hijau transgenik di Institut Kajian Perladangan (IKP), UPM Serdang, Selangor. Kelapa sawit bercambah pada umur 5 bulan digunakan untuk inokulasi menggunakan kaedah getah blok kayu (RWB). Data yang dikumpulkan dari sensor MEC10 diambil setiap jam melalui sistem dalam talian. Untuk mengenal pasti seberapa cepat perubahan dapat dilihat, analisis telah dilakukan pada minggu 3, minggu 7 dan minggu 12 selepas tanaman. Berdasarkan keputusan T-Test, kelembapan dan suhu tanah memberikan perbezaan yang signifikan pada semua minggu iaitu pada jam 6 pagi, 8 pagi dan 8 malam; dan 1-2am, 4 pagi-2pm dan 6 petang dan 8 malam. Kesimpulannya, BSR dalam benih kelapa sawit dapat dikesan seawal dalam 3 minggu selepas tanaman menggunakan kandungan lembapan dan nilai suhu tanah.

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List of Abbreviations

RWB	Rubber Wood Block
BSR	Basal stem rot
EC	Electrical-conductivity



Chapter 1 Introduction

1.1 Background

The oil palm tree (*Elaeis guineensis jacq.*) originated from West Africa was acquainted with Malaysia by the British in mid-1870's as a decorative plant. In mid 1960s, the development of oil palm expanded at any rate at a quick pace under government's horticulture enhancement program, which was acquainted with diminish the nation's monetary reliance on rubber and tin. Today, the production of the oil palm are largely in Malaysia in many type such as food source for human and animals, cosmetic and etc.

In the course of recent years, there have been misfortunes in palm oil generation and the nature of the oil palm creation additionally low because of different factors, for example, malady, water, supplements, soil substrate and so forth. Thus problems can be settled by controlling the plant growth factors such as light, temperature, and water. Management practices such as pot sizes, substrate, fertiliser supply, and planting density also can give impact toward physiological quality of oil palm seedling (Akpo et al, 2014)Terrible administration amid seedling can cause ailment on the basal stem root (BSR), brought about by the white-decay parasite named *Ganoderma boninense* which chop down the oil palm yield in Malaysia.

According to Wong et al. (2012), the disease was diagnosed in Malaysia oil palm plantation since 1928 which affected the oil palms at the age of 30 years and above. *Ganoderma* is one of the ailments that assault the oil palm tree on the basal stem root (BSR) causing genuine harm. BSR is the most widely recognized sign of the ailment, where dynamic rot of the root frameworks and at last of the lower

stem incites illness side effects. Water pressure, uneven mottling of the shelter, levelling of the crown, numerous unopened lances and creation of basidiocarps on the lower stems are the indications of the BSR (Turner, 1981).

Ganoderma infection can cause less water intake and absorption of nutrients from the root due to root systems damage. Alexander et al, (2017) demonstrate that the root tissue of oil palm seedling 6 month after inoculation with *Ganoderma boninense* showing root cortex section collapsed and formed a hollow between the epidermis and endodermis cells as due to cell death.

The earliest external symptoms of infection occur in foliage, generally after half of the cross-sectional area of the stem base has been destroyed by the *ganoderma* (Cabi, 2015). The damage lead to a restraint of water and nutrient toward a vital parts, causing signs such as water stress and malnutrition (Cabi, 2015). For young palm, external symptoms of basal stem rot are yellowing or mottling of the lower fronds, followed by necrosis .

There are numerous approaches to deal and control the BSR, such as social practices and natural control operators but, till now, no single control demonstrated to successfully control BSR in the field. In any case, early identification is imperative to control the illness adequately. It is done by monitor the soil properties of the current oil palm seedlings to distinguish the dampness substance and supplements content in connection to *Ganoderma boninense*.

1.2 Problem statement

Ganoderma boninense is one of the cause basal stem rot disease (BSR) and one of the main threats for oil palm industry. It causes big loss to yield production in Malaysia oil palm industry and increases economic losses. Assortment strategy have been utilized to control *ganoderma* contamination such as through fungicide treatment, natural control, evacuation of tainted palms and soil mounding, or even mix of these strategies. But, till now, no single control demonstrated to successfully control BSR in the field was accounted for (Susanto et al, 2005). Lab based approach such as *Ganoderma* Specific Medium (GSM), polymerase chain response DNA (PCR-DNA) and protein connected immunoserbent test polyclonal counter acting agent (ELISA-PAb) provide promising results of detection. However, such procedure is often difficult, far reaching and tedious (Lelong et al.2010; As'wad et al., 2011).

In order to avoid spreading of the disease in the plantation, it is important to detect the disease at nursery. It can be done by monitoring the condition of soil properties of oil palm seedling at nursery. With current advanced digital in electronics and sensing techniques, it is possible to have an alternative analysis which is simple mechanism and cheap to detect the condition of soil infected by *ganoderma* . By knowing the soil properties such as moisture content and nutrients content in the soil, the analysis in relation to *ganoderma* infection can be done.

1.3 Objective

General objective of this study is to monitor the soil properties (moisture content, electrical-conductivity (EC) and temperature) of inoculated and uninoculated Basal Stem Rot (BSR) in oil palm seedlings. Specific objective in this study are:

1. To determine the trend of soil properties taken from 3 different equipment.
2. To monitor moisture content, electrical conductivity and temperature of soil in inoculated and uninoculated oil palm seed.
3. To analyse the statistical data of soil properties on the soil properties of inoculate and uninoculated oil palm seed.

1.4 Scope and limitation

MEC 10 sensor was compared with, TDR 100, soil thermometer, Panasonic temperature, Land Mapper and EC probe to determine the trend of soil properties. Later, this study was conducted using MEC10 sensor with a controlled environment. The humidity and environment temperature was set as 60% and 20 °C to 35 °C respectively. Only three soil properties were studied i.e., soil moisture, EC and temperature. The age of the oil palm germinated seed used in this study is 5 month old. Rubber wood blocks (RWB) with the size of 3x3x3 cm was used as a source of *Ganoderma* inoculum. Watering was conducted automatically twice (9.00 a.m and 4 p.m.) using drip system. Meanwhile, fertilizer and pesticide were applied once in 3 weeks.

1.5 Thesis outline

Chapter 1 presents an introduction of this study. The introduction contribute the background of oil palm in Malaysia, problem statements, objective and scope and limitation of this study

Chapter 2 presents a literature review about the previous research on oil palm growth and oil palm at nursery stage and *ganoderma* symptoms and effect of *ganoderma* to the nutrient and water supply are also presented.

Chapter 3 presents methods used in this study to monitor the occurrence of *ganoderma*. This include the use of MEC10 to measure the soil properties namely soil moisture, EC and temperature. Later the trend of soil properties by MEC10 were compared with other equipment. It is followed by the experiment conducted in transgenic greenhouse to monitor the soil properties using 35 inoculated and 35 uninoculated oil palm seeds.

Chapter 4 presents the result and discussion on the trend of soil properties i.e soil moisture, EC and temperature in inoculated and uninoculated samples. The best hour for data collection and how early the infection can be detected are also presented.

Chapter 5 presents conclusion of this study. The main contributions of this thesis are clearly outlined. In addition, some suggestions on future work are also presented.

Chapter 2 Literature Review

2.1. The Oil Palm

The oil palm tree (*Elaeis guineensis jacq.*) begins from West Africa in the wild and later was form into agriculture crop. It was acquainted with Malaysia by the British in early 1870's as an ornamental plant. The development of oil palm expanded at quick pace in early 1960's under the administration's agriculture diversification program, which was acquainted with lessen the nation's monetary reliance on rubber and tree. The oil palm ranches in Malaysia are to a great extent dependent on the domain the board framework and smallholder conspire. Today, the creation of oil palm tree expanding starting at 2011, the absolute zone was 4.917 million hectares.

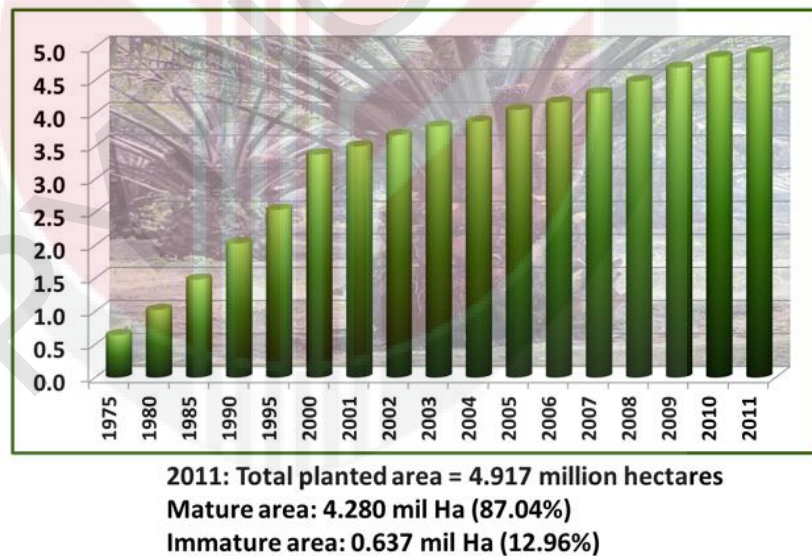


Figure 1: Planted Area of Oil Palm in Malaysia (Cabi, 2015).

Currently, the oil palm planted is the tenera hybrid which yields about 4.0 huge amounts of palm oil per hectare, together with 0.5 tons palm kernel oil and 0.6 tons palm kernel cake. Oil palm has a financial presence of around 25 years. The social

occasion of the oil palm could begin 30 months after field planting. The palm natural product is about the span of a little plum and is borne in enormous packs weighing between 10 kg – 50 kg a bundle can have up to 2000 organic products, each comprising of a hard kernel (seed) inside a shell (endocarp) which thus is encompassed by a fleshy mesocarp. The mesocarp is comprised of about 49% oil and about half kernel.

Malaysia is currently the second biggest maker of oil palm on the planet; in the wake of being overwhelmed by Indonesia in 2006. Since 1985, palm oil has turned into the second most expended oil on the planet, after soybean oil. A lot of worldwide creation in 1999 was half however in 2011, it diminished to 38%.

2.2. Oil Palm Seedling in Nursery

According to Akpo et al., (2014), a nursery is a place where plants are propagated and grown to usable size. It is a small plot in which the young oil palms develop. For a farmer, it is difficult to make the seeds of oil palms germinate because of some factors that need much care. For example, site preparation, planting and management. The selection of site for a nursery is critical and, whilst the sitting of it as centrally as possible to the area that the nursery is to provide palms for would appear desirable, the following considerations should hold highest priority:-

- a) The area is not prone to flooding or waterlogging.
- b) An unfailing, unpolluted water supply is available close at hand.
- c) Soil on site is of suitable quality and depth to allow for bag-filling to take place on site, throughout the intended life-span of the nursery.
- d) The area is not shaded out by adjoining crops or jungle trees.

- e) The location is such that security can be easily provided against theft, vandalism and pests.

Omore and Struik, (2014) state that there are two sorts of nursery, single stage and double stage. Double stage nurseries, contrasted with single stage nursery, are favored in light of the fact that they require less space and irrigation and take into consideration progressively effective upkeep and selection (culling). Nonetheless, the twofold stage nursery includes transplanting pre-nursery seedlings to the fundamental nursery, which whenever done inappropriately, may cause transplanting shock. Every nursery should have lockable stores for parts, devices and hardware and for synthetic substances and composts (close to a water supply). Herbicides must be plainly checked and kept independently from insecticides, fungicides and foliar composts to counteract pollution and erroneous taking care of.

2.3. The Oil Palm Disease

From F. O. Aderungboye, (2016) look into, there are thirty two infections and turmoil influencing the oil palm in Africa, Southeast Asia and South America are portrayed with their dispersion, monetary significance, etiology and control. Of these, nine sicknesses are viewed as a noteworthy financial significance, 19 are of minor significance, and four are because of nutrients insufficiencies. One of the real infections causing genuine financial misfortunes is *Ganoderma* trunk rot (*Ganoderma* spp.).

Rivera-Mendes, Cuenca, & Romero, (2016) said in Southeast Asia, basal stem rot (BSR) ailment has stayed one of the significant deterrents in oil palm development. It is caused by the white-rot fungus, *Ganoderma boninense* which

cut down the oil palm yield in most production area in Malaysia as well as Indonesia.

2.3.1. *Ganoderma boninense* caused a root infection and lower stem inversion.

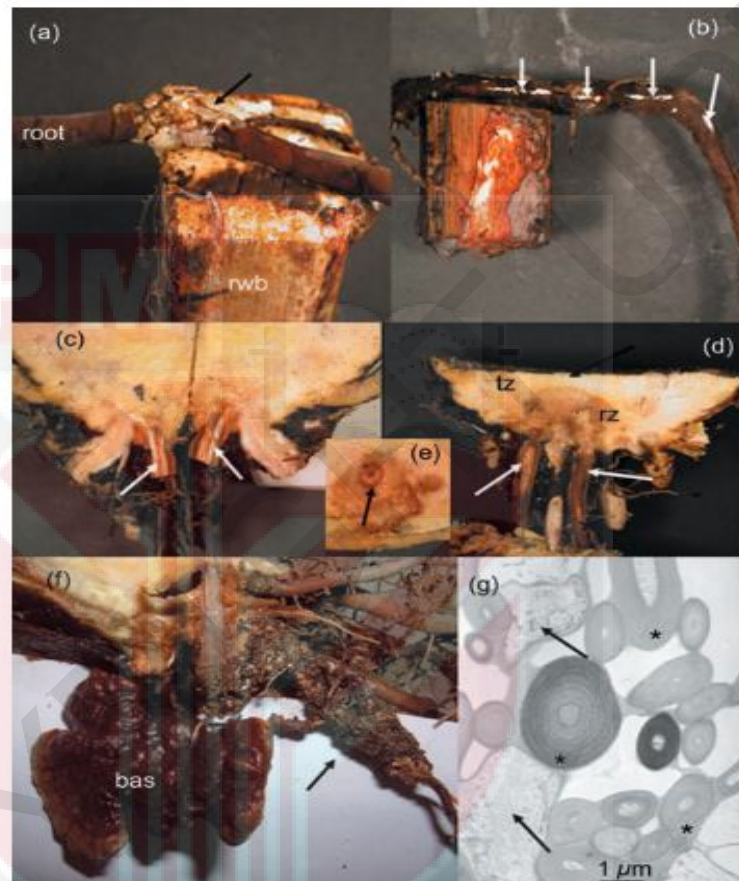


Figure 2: Penetration of intact roots of oil palm (*Elaeis guineensis*) by *Ganoderma boninense* prior to bole infection (Rees, Flood, Hasan, Potter, & Cooper, 2009).

From Figure 2 (a), an oil palm root with mycelial growth around the root firmly attached on colonized rubber –wood block (RWB). Figure 2(b) show *G. boninense* white mycelium protruding through the epidermis of an infected root (arrows). It cause Infection at the root-stem interface and cause two roots are infected (discoloured brown, arrows) but with no visible necrosis in the stem base (Figure 2 (c)). Figure 2 (d) show the advance of the fungus into the

stem base (bole) tissue from infected roots (arrows). Infected tissue appears brown; the perimeter of this region is typically dark brown and immediately in advance of the infected area is an arrow area of yellow tissue; these have been termed the 'reaction zone' (rz) and 'transition zone' (tz), respectively, (Rees et al., 2009). Uninfected tissue is cream- coloured. Figure 2(e), transverse section showing spread of necrosis into bole parenchyma from one infected root (arrow).

Figure 2(f) is uninfected root with fungal, melanised pseudo-sclerotium covering the surface of the root connecting with a basidiocarp which has emerged from the stem base. Figure 2(g) is transmission electron micrograph of melanised pseudo-sclerotium cells. Note some hyphae have extremely thick, melanised, lamellate, cell walls with little or no cytoplasm whilst others retain thin wall and cytoplasm (arrows).

2.4. *Ganoderma boninense*.

Ganoderma is characterized by basidiocarpe large, perennial, woody brackets which are lignicolous and leathery, sometimes with a stem. The fruit body typically grow in a fan or hoof-like form on the trunks of the trees. They have double-walled, truncated spores with yellow to brown ornamented inner layers. Previous research found *Ganoderma boninense* isolated from either neighbouring or distant trees supports the belief that sexual reproduction plays an important role in the epidemiology of Basal Stem Rot (BSR) disease (Pilotti et al. 2013).

Ganoderma life cycle consist of a number of alternative and consecutive events. Firstly, there must be an injury expose the wood. The cells around the injured area oxidized and discolour due to biochemical exchange. This

discolouration can develop further if the wound remains open to the many microorganisms which can land and grow on the moisture. Finally, as the wood-rotting fungi (*Basidiomycetes*) integrate, digestion of cell wall components begins. These microorganisms, however, are confined to the area which is already under gone the biochemical processes followed by bacterial reaction. While these remain in tissues inside the endodermis in the internal stages their hyphae may be detected in different cells and tissues in advanced stage of disease. Idris, Kushairi, Ariffin, & Basri, (2006), revealed that the formation of black line within the infected tissues observed in the stem of oil palm infected with *G. boninense*.

2.5. Symptoms of *Ganoderma*

Ganoderma, a fatal fungal disease of oil palm plantation and has significant impact on the production of oil palm in Malaysia. The earliest external symptoms of basal stem rot of oil palms occur in the foliage, generally after at least half of the cross-sectional area of the stem base has been destroyed. Decay leads to a restriction of water and nutrient supply to the aerial parts, causing symptoms resembling those of water stress and malnutrition (Turner and Gilibanks, 1974). In young palms, external symptoms of basal stem rot comprise a yellowing or mottling of the lower fronds, followed by necrosis. Young unfolded leaves become chlorotic and may be reduced in length, sometimes with necrotic tips. As the disease progresses, palms may take on a pale appearance, with retarded growth and spear leaves remaining unopened. Similar symptoms are observed in mature palms, with multiple unopened spear leaves and a generally pale leaf canopy. Ultimately, affected palms may die, the necrosis beginning with the oldest fronds

and extending to younger regions of the crown. Palms normally die within 6 to 12 months after the appearance of unexpanded spear leaves.

Characteristic internal symptoms appear as light-brown dry rot lesion of both the stem and bole, occasionally with visible mycelial growth and narrow, dark bands of tissue between the light-brown lesions. Uninfected tissues outside the leading edge of the lesion area are frequently yellow-pigmented, which may represent a host-resistance response to infection. Infected root tissues are generally friable, with dry and powdery internal tissues (Idris et al., 2006). In older roots, the fungus may be observed as a whitish skin-like layer on the inner surface of the exodermis; cortical tissue becomes brown and ultimately disintegrates, whilst the stele appears black.

2.6. Effect of *ganoderma* based on the nutrient and water supply to the aerial part.

2.6.1. Root tissue damage caused of inoculant fungus, *G. boninense*

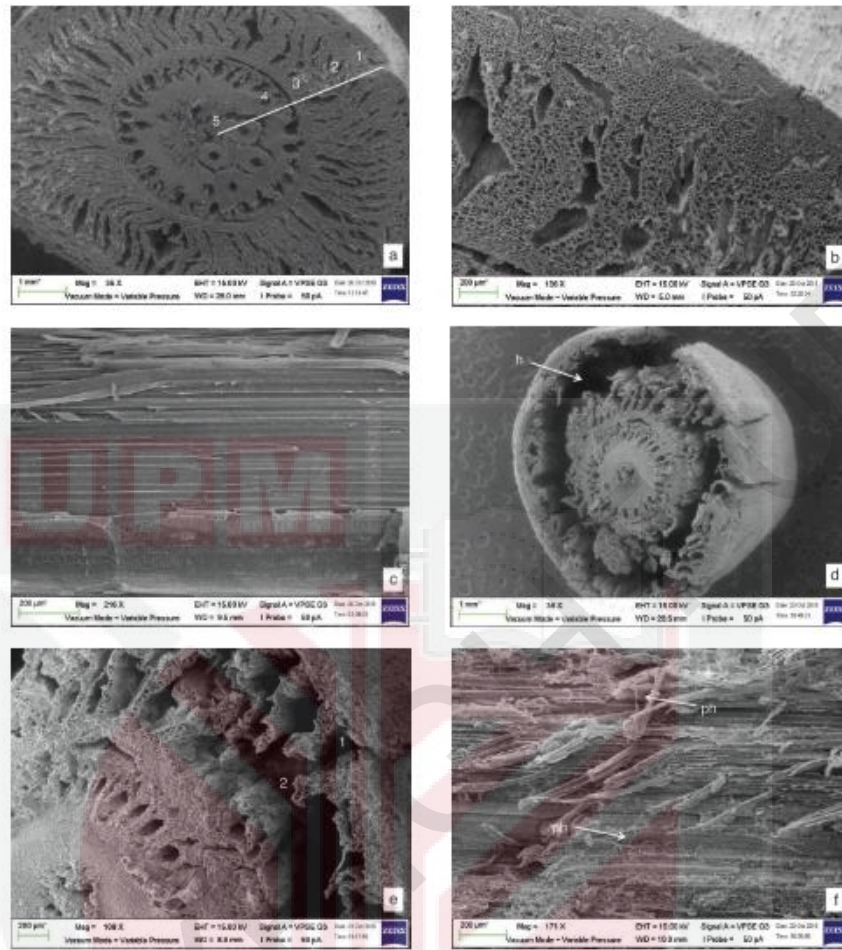


Figure 3: Scanning electron microscopy (SEM) images of root tissue of oil palm seedlings free of inoculant fungus, *G. boninense*, (Alexander, Sipaut, Dayou, & Chong, 2017).

Alexander et al, (2017) proved that *Ganoderma boninense* give effect to oil palm roots. Figure 2(a) show the view of cross-section of uninoculated oil palm seedling revealing an intact and undamaged cell structure, where five zones 1-5 are generally distinguished; 1- epidermis; 2 - cortex; 3 - vascular bundles; 4 - medullary vessels; 5 - pith. Figure 3(b) is close-up view of zone 1 and 2 of Figure 1a showing a healthy-looking cortical cells.

Figure 3(c) is transversal section view of uninoculated cortex tissue showing a smooth and undamaged structure. SEM of root tissue of oil palm

seedling 6 months after inoculation with *G. boninense* showing root cortex section collapsed and formed a hollow indicated as 'h' in between the epidermis and endodermis cells as due to cell death, however the vascular system remain intact but distorted. Figure 3(e) is a disintegrated and disorganised structure of the epidermal indicated as '1' and cortical cells indicated as '2'. Figure 3(f) is detailed view of zone 2 (refer to Figures 1a and 1e of infected root showing intense damages and highly colonised with *G. boninense* mycelia indicated as 'ph'.

This research revealed that the water and nutrient transport in the root to the leaves were affected by the basal stem rot (*G. boninense*). The soil moisture in infected seed is less than the uninfected seed meanwhile the nutrient uptake from infected seed is higher than the uninfected seed. This is proven by another researcher, Duniway, 1977; Changes in Resistance to Water Transport in Safflower during the Development of Phytophthora Root Rot.

2.6.2 Effect of disease (Phytophthora Toot Rot) on nutrient uptake.

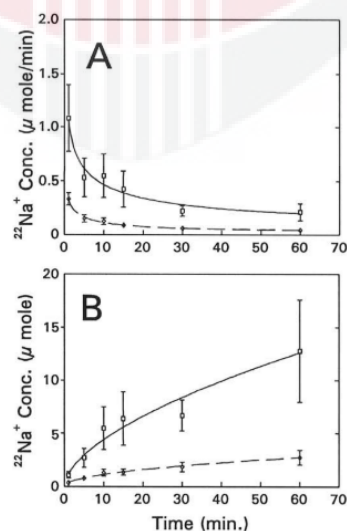


Figure 4:Na+ concentration in roots over time (Duniway, 2009).

Figure 4(A) show the rate of Na^+ by healthy root is less than the infected root, Figure 4(B). Infection might cause physical and physiological damage to root membrane systems, thus reducing selective permeability. Sodium competes with potassium, calcium, magnesium and ammonium for uptake by the plant. Chloride can compete with nitrate, phosphate and sulphate uptake. Therefore, if sodium or chloride is high in the growing medium, while other beneficial elements are at low or normal levels, the plant, which cannot tell them apart, will take up what is in the growing medium. Therefore the plant may not acquire sufficient levels of a required beneficial element and can leads to its deficiency in the tissue (Duniway, 2009).

Chapter 3

Methodology

In this chapter, a method used to monitor the soil properties in inoculated and uninoculated oil palm seedling are presented. Firstly, lab work have done to comparing the MEC10 with other equipment by measuring soil properties namely soil moisture, temperature and electrical-conductivity. Later, this study was conducted in transgenic greenhouse to monitor the soil properties in inoculated and uninoculated oil palm seed. Three parameters were measured in this study namely moisture content, electrical-conductivity and temperature.

3.1. Lab work

3.1.1. Organism

The medium used in this study are mix topsoil, peat soil and sand with ratio 3:2:1 respectively

3.1.2. Sample preparation

Soil samples were air-dried by spreading the soil samples out across newspaper. The stones, rocks, roots or other unwanted materials were removed and any large clumps were break down by sieve using shaker.

a) Soil Moisture

First, all the apparatus such as aluminium ring and container were weighted. The soil then was transfer in medium container to measure the moisture content using the TDR 100 and MEC10. The whole probe of sensor was burried into the soil to get an accurate reading. Next, the soil was chopped by aluminium ring.

Weight of aluminium ring with soil was recorded and it was labelled as No.1.

After that, the soil sample in container was added with 50 ml water and mix together. The same steps are repeated using 100 ml, 150 ml, 200 ml, 250 ml and 300 ml of water. The samples then labelled as No.2, 3, 4, 5, 6 and 7 respectively.

Lastly, all samples were put into the oven with 105°C for one day.

After one day, weight of aluminium ring with soil were recorded again.

b) Electrical Conductivity (EC)

This experiment was carried out with 4 polybags which contain same weight of soil and same level of water with ratio 1:5 respectively. 10 gram air-dry soil were prepared in each polybag and left outside the laboratory and the fertilizer given were 0.5 g, 1.0 g, 1.5 g and 2.0 g respectively.

The data were collected 3 times at certain hour and the readings were taken using three different sensors i.e., MEC 10 and LandMapper and EC probe.

c) Temperature

First, this experiment was carried out with only one sample of polybag filled by soil. The samples were watered at 8 a.m with same water level and left outside the lab. The data were collected for every 2 hours after watered at 9 a.m, 11 a.m, 1 p.m, 3 p.m, and

5 p.m. The data were taken by three different sensors (MEC 10 sensor, soil thermometer and Penasonic temperature controller).

3.1.3. Equipment

a) MEC10



Figure 5:MEC10 sensor.

MEC10 is a sensor which can give reading of moisture content, EC and temperature. It is an important tool to observe and study the occurrence, evolution, improvement and the dynamics water of saline soil. This MEC10 sensor can measure the volume of soil moisture.

The soil moisture measurement method is in line with international standards at present. The sensor has the following characteristics:

1. Soil moisture content, electrical conductivity and temperature three parameters.
2. One solution can also be used for fertilizer, and other nutrient solution conductivity matrix.

3. Electrode using special treatment of the alloy material, can withstand a strong external impact, not easy to damage.
4. Completely sealed, acid and alkali corrosion, can be buried in the soil or directly into the water for long-term dynamic testing.

b) TDR100

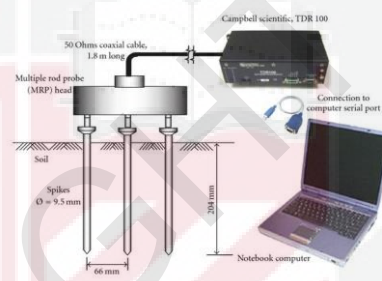


Figure 6: Time Domain Reflectometry (TDR) 100 equipment.

The underlying principal of TDR involves measuring the travel time of an electromagnetic wave along a wave-guide. The speed of the wave in soil is reliant on the mass dielectric permittivity (ϵ) of the soil matrix. The way that water ($\epsilon = 80$) has an a lot more prominent dielectric consistent than air ($\epsilon = 1$) or soil solids ($\epsilon = 3-7$) is misused to decide the volumetric water contain (VWC) of the dirt. The VWC estimated by TDR is a normal over the length of the waveguide.

When taking the measurement, it is significant that the rods be completely embedded into the soil. If not, part of the sampling volume will be composed of air and the reading will be inaccurately low. For the same reason, the probe should be inserted with a steady, downward

pressure. If the rods are wiggled into the soil, air pockets can be created adjacent to the rods that will result in low readings.

The TDR can be set to one of two VWC modes, Standard or High Clay. The standard mode will be suitable for most mineral soils. The high Clay mode will be progressively exact for soils with higher dirt substance. What's more, the meter can likewise show relative moisture content (RWC) and water deficiency. RWC is a record esteem determined as for upper (wet) and lower (dry) VWC set point. For instance, expect the dry set point is $VWC=25\%$ and the wet set point is $VWC=40\%$. On the off chance that the meter estimated a VWC of 35% , this would mean a RWC of 67 in light of the fact that 35% is $2/3$ somewhere in the range of 25% and 40%). On the off chance that the dirt's volumetric water substance is outside the scope of the set focuses, it is conceivable to get a negative RWC or a RWC more prominent than 100 .

c) Soil thermometer



Figure 7: Soil thermometer.

This soil thermometer or soil probe thermometer is suitable for measuring the temperature of soil, manure or comparable, perfect

for the horticulturist or sharp cultivator. It is measure temperature over the scope of 0 to 80°C in 1°C increase.

d) LandMapper



Figure 8: LandMapper ERM-02.

LandMapper ERM-02 is the series device and allows not only measure ER and EC using artificial applied electrical current and four-electrode probe, but also study natural electrical fields in soils and plants with patented non-polarizing electrode. To set, a four-electrode test is set on the dirt surface and an electrical resistivity or conductivity esteem is perused from the advanced presentation.

The gadget can quantify ER and EC in a surface soil layer of profundity 2 cm down to 20 m, which is set by shifting the measure of a four-electrode test.

3.2 Soil properties monitoring for inoculate and uninoculated oil palm seed.

The experiment was conducted in a greenhouse located at Institute of Tropical Forestry and Forest, Universiti Putra Malaysia, Serdang, Selangor. The experiment was started from 25th January to 19th April 2019 (4 months period). The experiment has 70 oil palm seedling (35 inoculated and 35

uninoculated, temperature (28°C - 30°C), and the average relative humidity during study periods are 60%. Fertilizer was applied once in 3 weeks and watering was done twice in a day, 9.00 a.m and 4.00 p.m. (from week 1 until week 4 planted) and once at 10.00 a.m for next watering using drip system automatically.

3.1.4. Organism

The medium used in this experiment are mix topsoil, peat soil and sand with ratio 3:2:1. respectively.

3.1.5. Sample preparation

This experiment was conducted under shelter in Universiti Putra Malaysia with air temperature 23-38°C. Oil palm seeds GH500, across-breed product between Elite Deli Dura and second generation of Pesifera, BM119, were used in this study. 90 Polybag media were prepared by mixing topsoil, peat and sand at the ratio (3:2:1) respectively. The study was carried out with 45 polybags infected by *ganoderma*, 45 polybags unaffected by *ganoderma*. The seedlings were put in shaded area watered twice a day and fertilizer, N-P-K applied weekly (1.0 g per polybag) from week 7 to week 12 after sowing.

The oil palm seed are seat on the rubber wood block and to get affected oil palm seed, it was seated on the *ganoderma* wood block. Next, the oil palm seed were arrange on the bench as shown in Figure 12. Soil moisture, electrical-conductivity and temperature then are monitored using MEC10 sensor and the data will collected through software in computer.

Chapter 4 Result and Discussion

This chapter presents the trend soil properties i.e., soil moisture, electrical-conductivity and temperature in inoculated and uninoculated samples. The best hour for data collection and how early the infection can be detected are also presented.

4.1. Data analysis of sensor reading.

a) Soil moisture

Soil moisture content reading was taken seven times with different volume of water by using MEC 10 sensor and TDR 100 sensor. The reading was also taken using a standard oven dry method by calculating the volumetric water content (%).

The calculated for volumetric water content (VWC) for each samples are as below:

Table 1: Moisture content reading taken from MEC10, TDR 100 and oven dry method.

No.	Volume Of Water Added (ml)	MEC10 (%)	TDR100 (%)	Oven Dry Method			
				GWC	Bulk Density	VWC	Mean VWC (%)
1	0	4.44	2.7	0.023	2.6	0.06	0.05
				0.021	2.3	0.05	
				0.018	2.6	0.05	
2	50	5.37	3.3	0.059	6.6	0.39	0.38
				0.058	6.8	0.39	
				0.058	6.4	0.37	
3	100	5.7	3.4	0.096	9.8	0.94	0.99
				0.099	10.5	1.04	
				0.097	10.2	0.99	
4	150	7.27	4.2	0.142	12.2	1.73	1.65
				0.137	11.3	1.52	
				0.140	12.2	1.71	
5	200	13.31	6.2	0.187	16.2	3.03	3.01
				0.186	16.1	2.99	
				0.187	16.1	3.01	
6	250	15.45	7.7	0.210	19.9	4.18	4.36
				0.217	20.8	4.51	

				0.217	20.2	4.38	
7	300	23.63	11.6	0.261	36.5	9.53	9.62
				0.261	36.3	9.47	
				0.263	37.5	9.86	

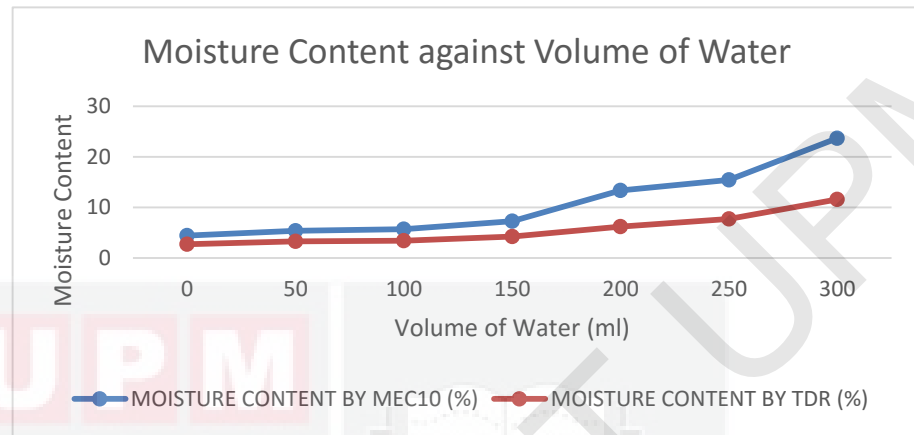


Figure 9: Moisture content against volume of water based on different type of sensor.

As expected, based on the graph in Figure 9, the trend of graph for both sensor are similar. The graph shows the both line are slightly increase as the volume of water increase. There is not much difference between moisture content measured by MEC 10 sensor and TDR 100 sensor.

b) Temperature

For temperature, the sample was placed under unshaded place i.e., direct with sunlight. The data was recorded at six times. An initial temperature, T_0 was defined as temperature reading before pouring the water into the soil. The soil with water was then measured at 9.00 am (T_1), 11.00 am (T_2), 1.00 pm (T_3), 3.00 pm (T_4) and 5.00 pm. (T_5).

Table 2: Temperature reading using different sensor at different time.

Time	Temperature ,°C		
	MEC 10	Panasonic temperature	Soil thermometer
T_0	26.1	28.0	30.0
T_1	26.8	27.8	28.0
T_2	29.0	27.3	29.0
T_3	30.1	29.5	32.0
T_4	31.5	31.2	32.5
T_5	27.3	28.7	29.0

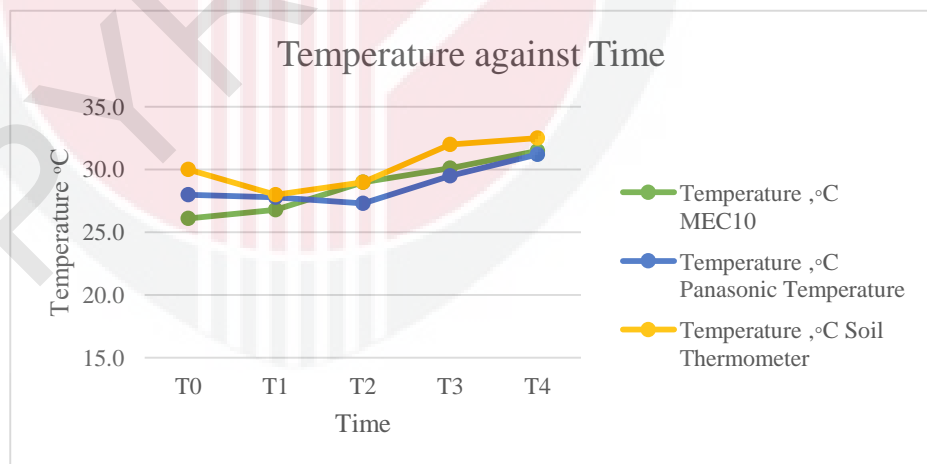


Figure 10: Temperature against time with different sensors.

Based on the graph in Figure 10, it shows as expected result which is the trend of graph for three sensors are similar. The graph shows the lines are slightly increase and drop as the time increase. There is not much difference between temperature value measured by MEC 10 sensor, soil thermometer and Panasonic temperature controller.

c) Electrical-conductivity (EC)

For electrical-conductivity (EC), three sensors were used to determine the value of EC in soil. The fertilizer are added three times with same weight at three place.

Table 3: Electrical-conductivity readings with different sensor.

Amount of fertilizer add (g)	MEC 10 (ds/cm)	Land Mapper ($\Omega.m$)	EC probe ($\Omega.m$)
0	36	1.377	979
15	2055	50.91	630
30	3979	21.86	544
45	5211	17.29	502

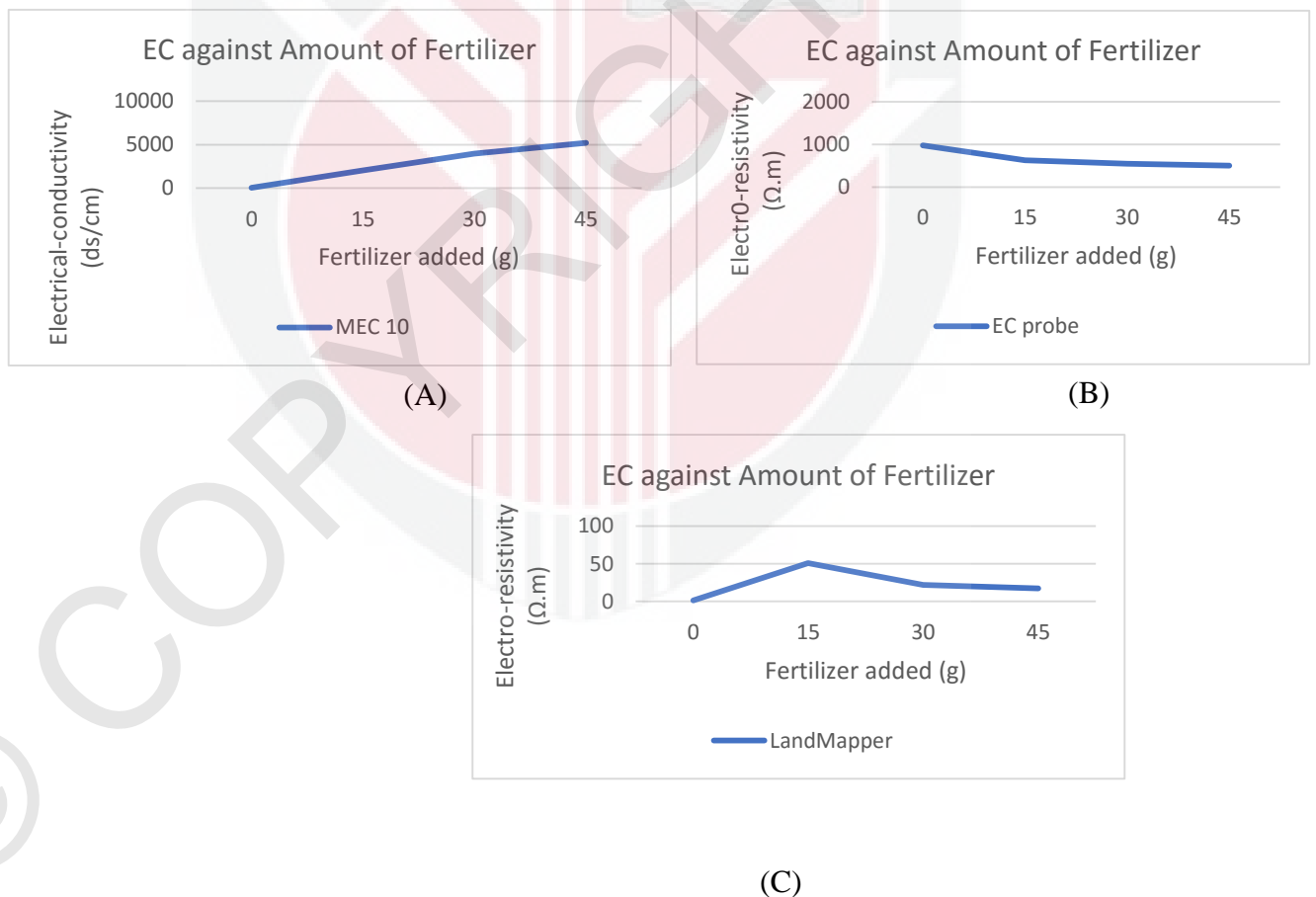


Figure 11: Electrical-conductivity against fertilizer.

From the result shown in Figure 11, the graph of MEC10 was inverted with EC probe and LandMapper. This is because, the unit of MEC10 is not same with EC probe and LandMapper. MEC10 sensor read soil electrical-conductivity while EC probe and LandMapper read soil electro-resistivity.

Conductivity and resistivity are inversely proportional to each other. When conductivity is low, resistivity is high (“Electrical Conductivity and Resistivity - Chemistry LibreTexts,” 2019). The equation is as follows:

$$\rho=1/\sigma$$

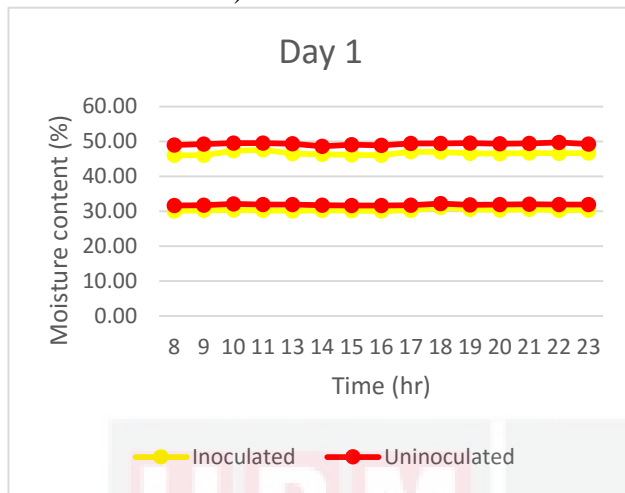
Where, Resistivity is represented by ρ and is measured in Ohms (Ωm),

Conductivity is represented by σ and is measured in Siemens ($1/\Omega\text{m}$).

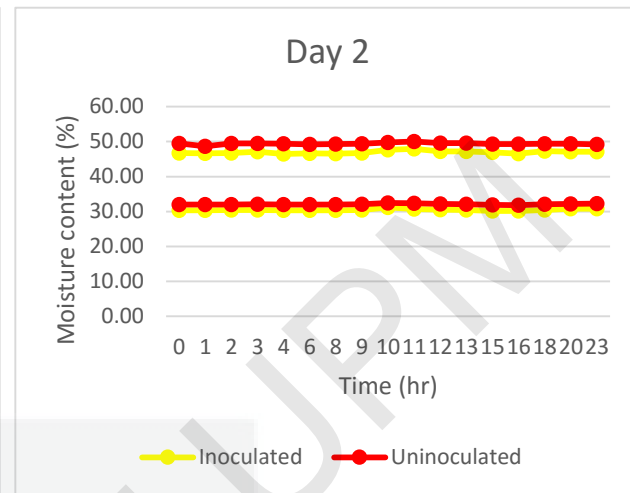
In conclusion, MEC10 can be used for measure soil properties such as soil moisture, electrical-conductivity and temperature. This is because, the trend of the soil properties when measured by MEC10 are same with other equipment. MEC10 also can be used for measure any type of plant and can measure at any place.

4.2 Data analysis of soil properties monitoring.

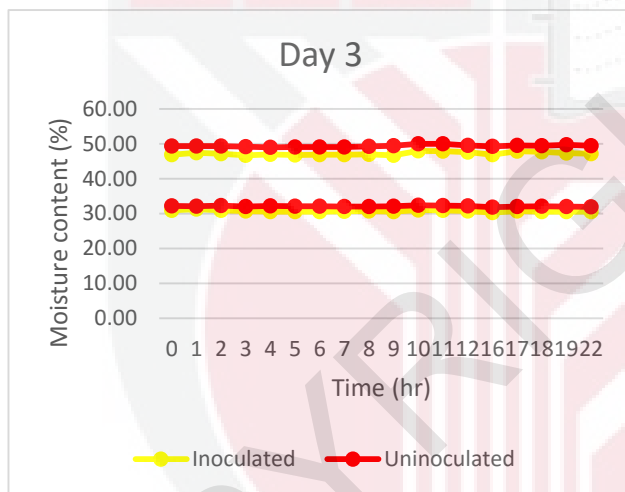
a) Soil moisture



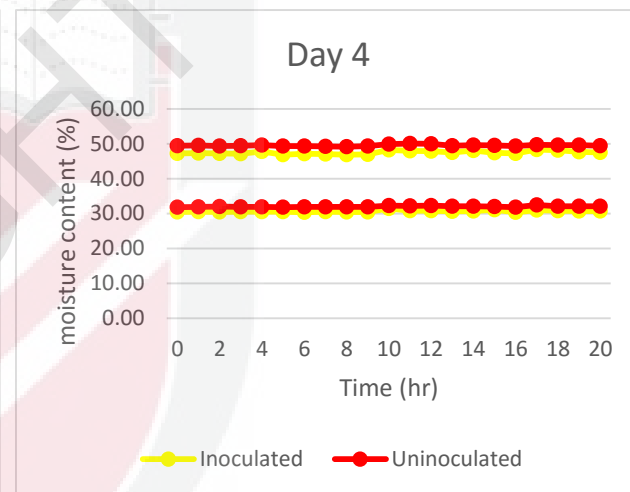
(a)



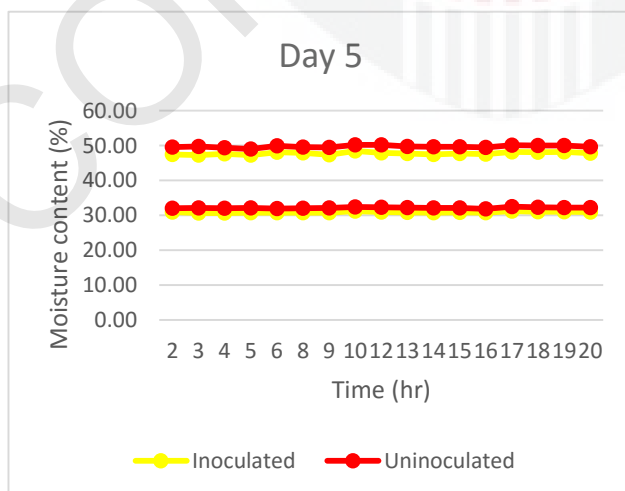
(b)



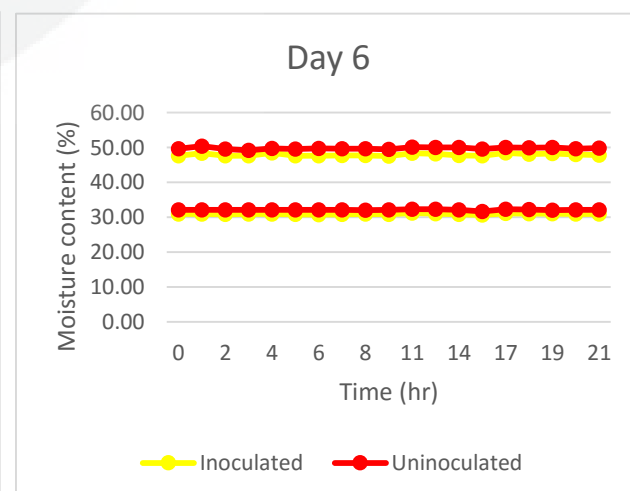
(c)



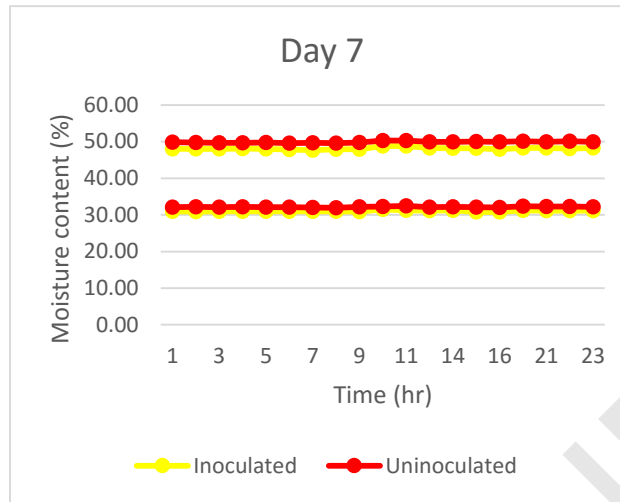
(d)



(e)



(f)



(g)

Figure 12: Average moisture content (%) of inoculated and uninoculated of oil palm seed taken from Week 3. (a) Day 1. (b) Day 2. (c) Day 3. (d) Day 4. (e) Day 5. (f) Day 6. (g) Day 7.

Based on Figure 12, in week 3, there are 4 lines which represent 2 line of inoculated and 2 line of uninoculated. The line showed the big difference between two line of inoculated and uninoculated. Inoculated and uninoculated oil palm seed has high moisture because they were placed far from the humidifier and air conditioner. While, inoculated and uninoculated oil palm seed which has moisture content 30% to 35% were place close to humidifier and air conditioner. Then, moisture content in uninoculated and inoculated oil palm seed show the consistent result but uninoculated is more moisture than inoculated oil palm seed.

Table 4: Average of moisture content in inoculated and uninoculated oil palm seed by time.

No	Week 3		Week 7		Week 12	
	Inoculated	Uninoculated	Inoculated	Uninoculated	Inoculated	Uninoculated
1	28.25	29.62	31.31	32.20	31.10	32.12
2	27.87	29.35	31.26	32.12	31.14	32.08
3	27.52	28.35	31.24	32.13	31.09	31.95
4	27.22	28.73	31.32	32.11	31.07	31.96
5	26.83	28.44	31.26	32.09	31.12	32.09
6	26.41	28.08	31.25	32.11	31.46	32.03
7	25.96	27.62	31.17	32.10	30.97	32.00
8	25.69	27.25	31.18	32.09	31.04	31.74
9	25.57	27.17	31.19	32.10	31.09	32.06
11	27.52	29.31	33.43	33.65	33.13	33.51
12	28.16	29.89	32.91	33.44	32.47	33.30
13	29.02	30.84	32.69	33.23	32.15	33.00
14	29.85	31.70	32.39	33.07	31.88	32.71
17	30.80	32.44	31.85	32.64	31.10	32.00
19	26.93	31.13	31.77	32.43	30.98	31.84
20	29.55	31.06	31.60	32.27	31.01	31.83

Based on the graph in Figure 13, in general the moisture content of uninoculated oil palm seed is higher than inoculated oil palm seeds in every week. The minimum moisture content is 25.57% which is on week 3 at 9 am from inoculated oil palm seed and the maximum moisture content is 33.51%. While for uninoculated oil palm seed, the moisture content is 33.51% at week 12 and the minimum moisture content is 27.17% at week 3 and the maximum water content is 33.51%.

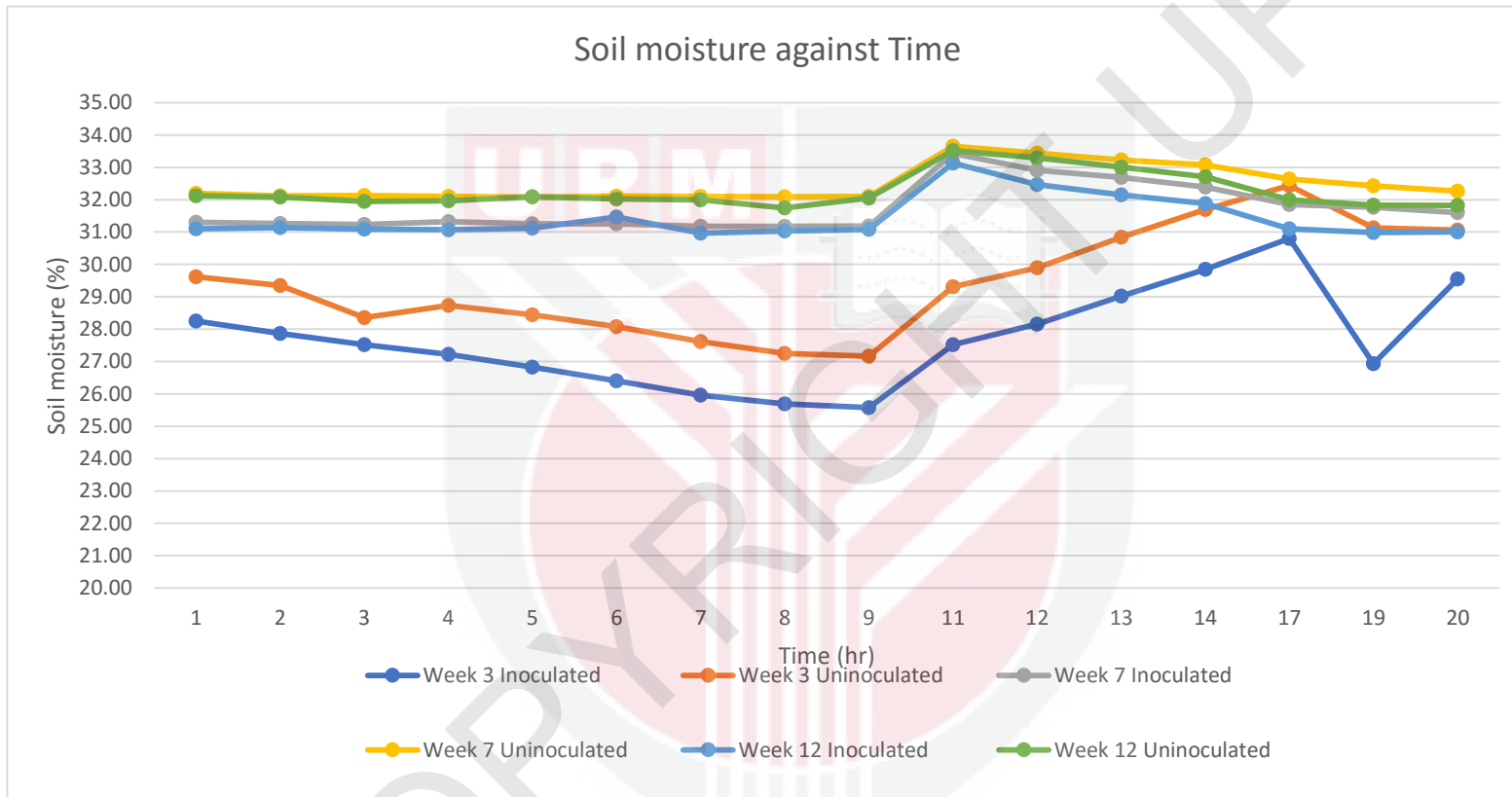
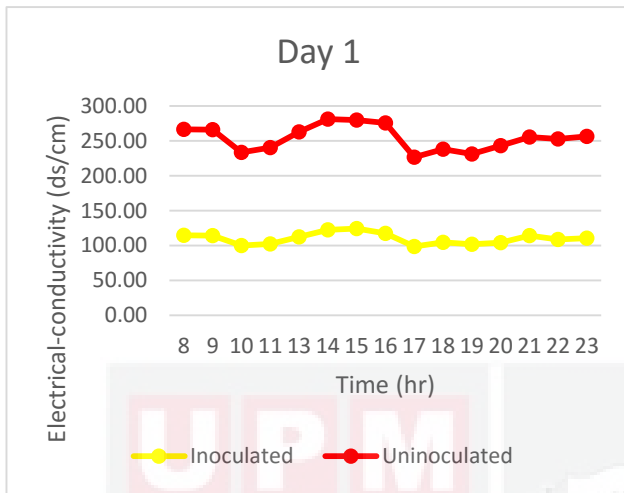
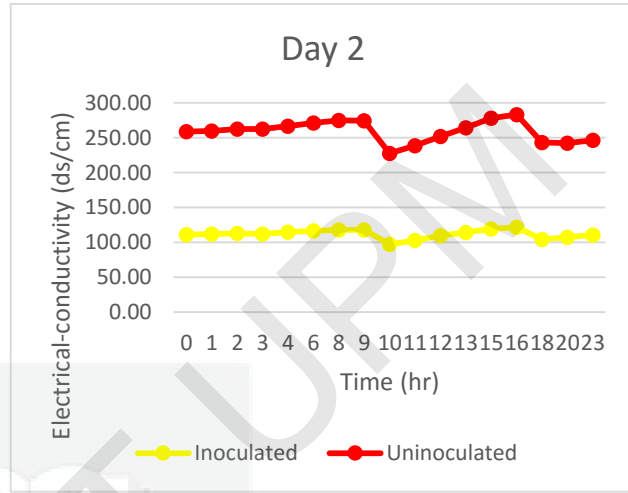


Figure 13: Average value of moisture content against time for week 3, 7 and 12.

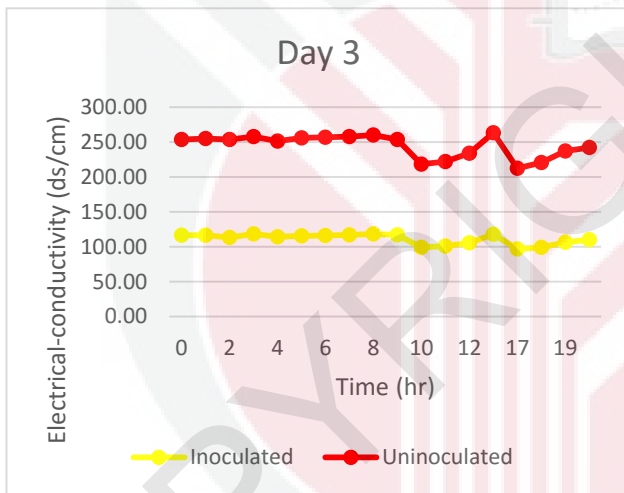
b) Electrical-conductivity



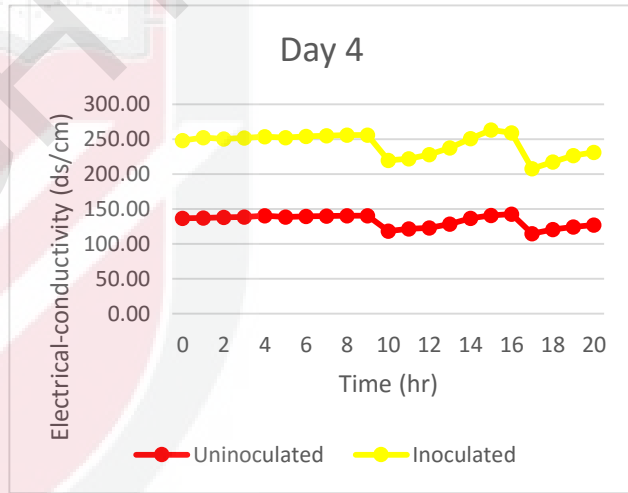
(a)



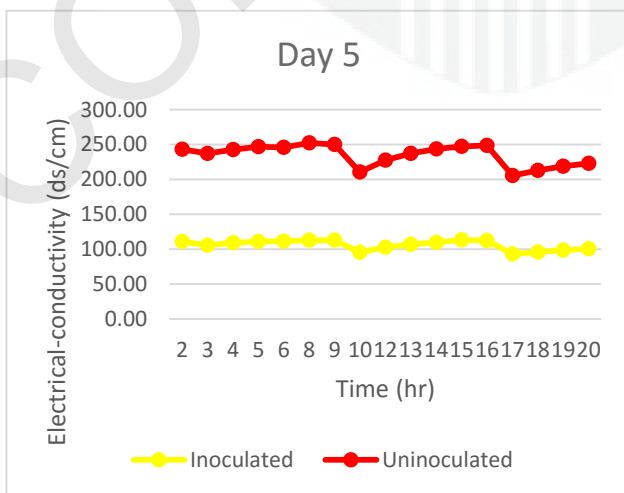
(b)



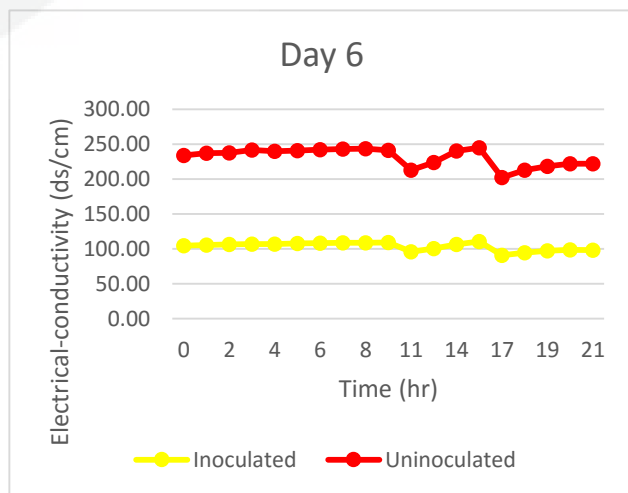
(c)



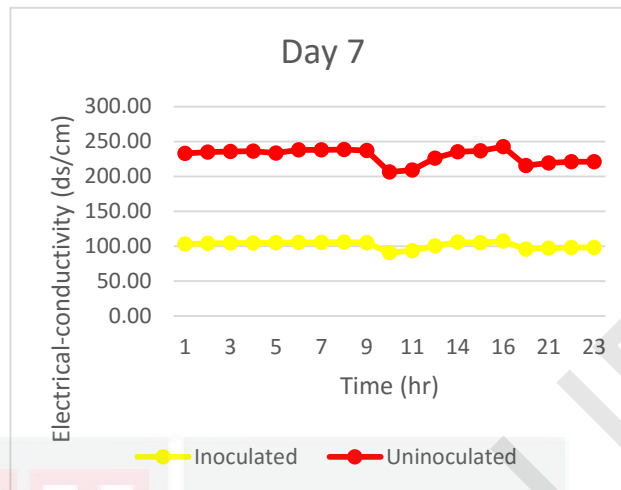
(d)



(e)



(f)



(g)

Figure 14: Average of electrical-conductivity (EC) ds/cm of inoculated and uninoculated oil palm seed in Week 3. (a) Day 1. (b) Day 2. (c) Day 3. (d) Day 4. (e) Day 5. (f) Day 6. (g) Day 7.

Based on Figure 14, on week 3, the difference of EC reading between inoculated and uninoculated is bigger than on week 7 and 12. The range of EC value for uninoculated on week 3 is 127 ds/cm until 159 ds/cm. While, the range for inoculated is 90 ds/cm to 150 ds/cm.

Table 5: Average of electrical-conductivity in inoculated and uninoculated oil palm seed by time.

No.	Week 3		Week 7		Week 12	
	Inoculated	Uninoculated	Inoculated	Uninoculated	Inoculated	Uninoculated
1	115.20	137.53	184.65	211.03	141.22	152.15
2	112.62	138.25	184.78	211.17	141.40	153.18
3	113.33	138.92	185.38	211.98	142.22	153.52
4	113.18	140.52	186.92	213.43	142.83	154.35
5	114.07	138.63	188.58	215.50	148.38	157.02
6	114.63	139.73	190.15	217.18	144.77	156.22
7	115.12	140.07	191.08	218.40	142.42	157.63
8	115.60	140.40	191.45	218.75	144.60	161.05
9	115.77	140.57	190.92	218.32	143.10	154.32
11	100.32	121.73	186.88	191.07	108.83	112.85
12	104.95	123.32	183.03	207.08	118.73	123.28
13	109.37	128.58	184.12	208.02	129.58	135.03
14	114.30	136.80	187.38	210.08	134.53	143.00
17	93.20	114.93	194.55	217.30	142.27	149.37
19	102.25	124.53	199.75	216.38	141.05	147.23
20	104.32	127.23	189.08	209.20	137.25	140.80

Based on Figure 15, the electrical-conductivity of uninoculated oil palm seedling gave higher EC than inoculated oil palm seedling for all weeks. However, on week 7, electrical-conductivity for inoculated and uninoculated is higher followed by week 7 and week 12. Higher EC on week 7 because of fertilizer was applied. EC reading can be affected because of the high moisture content and fertilizer clump at sensor area which cause the gap between uninoculated and inoculated become smaller from week to week. The highest of electrical conductivity also because of the control environment such as humidity and temperature. This also can be a reason the graph of electrical conductivity was drop at 11 a.m.

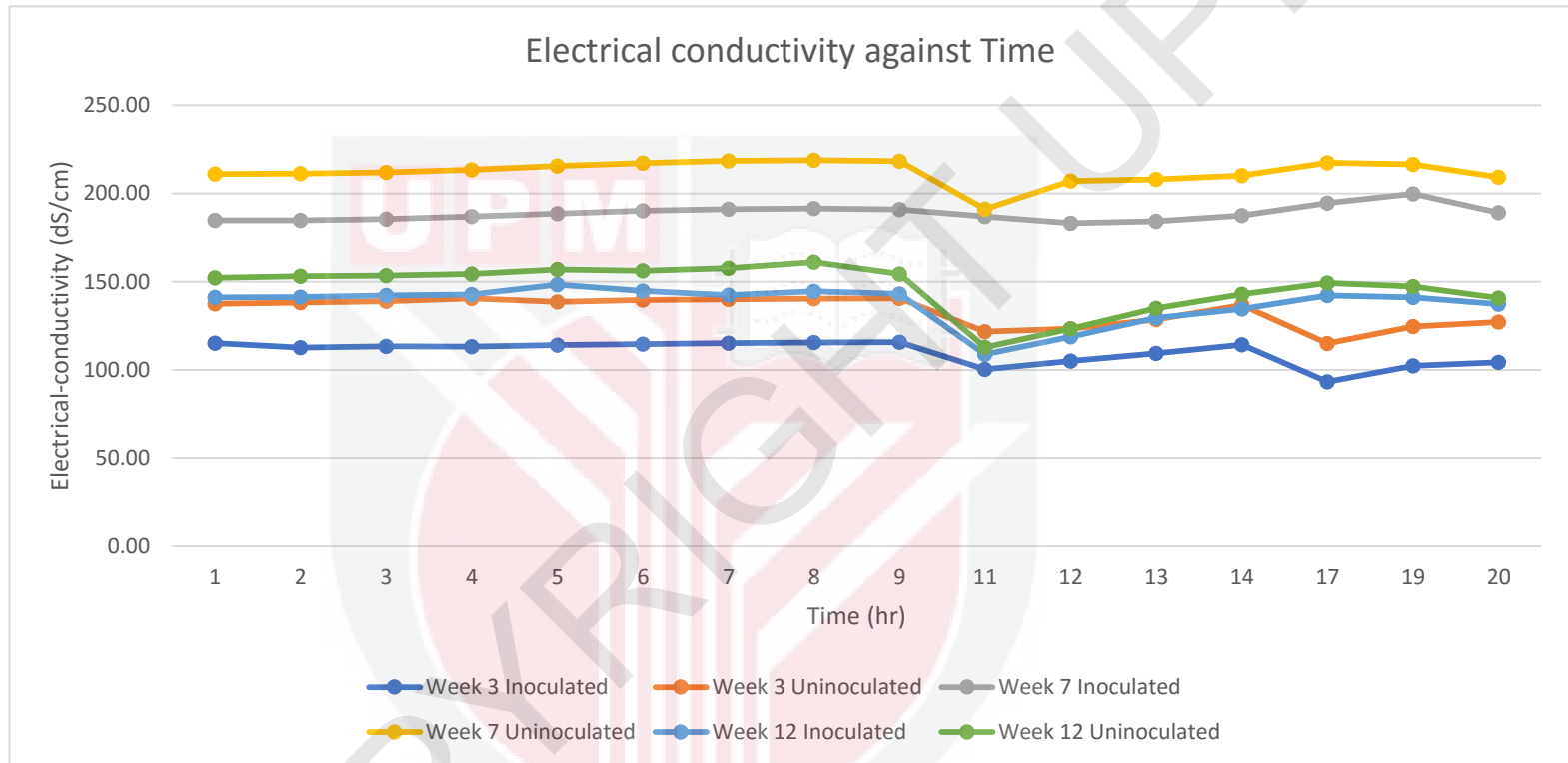
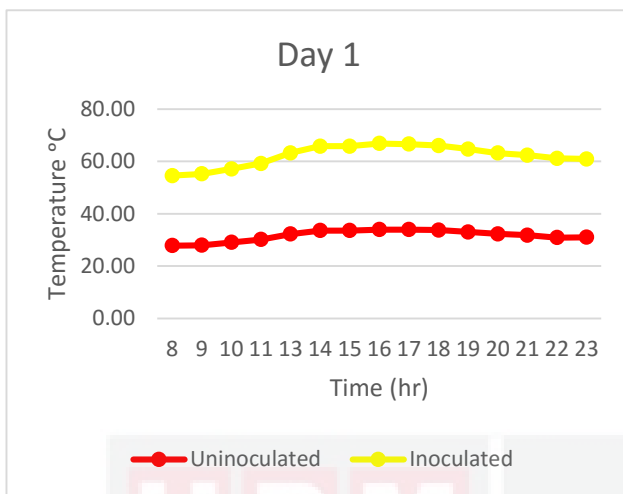
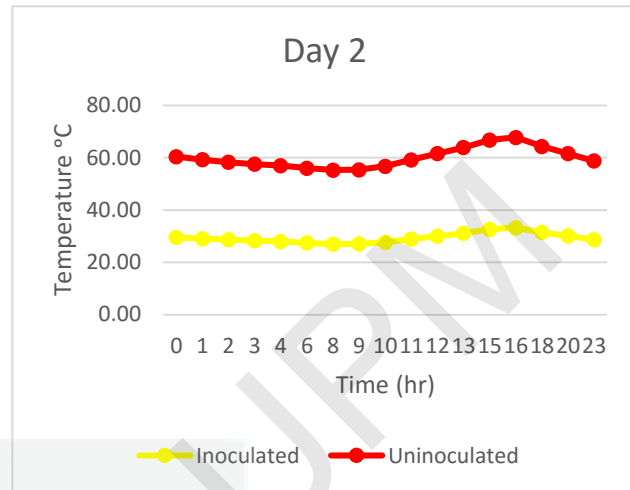


Figure 15: Average value of an electrical-conductivity against time for week 3, 7 and 12.

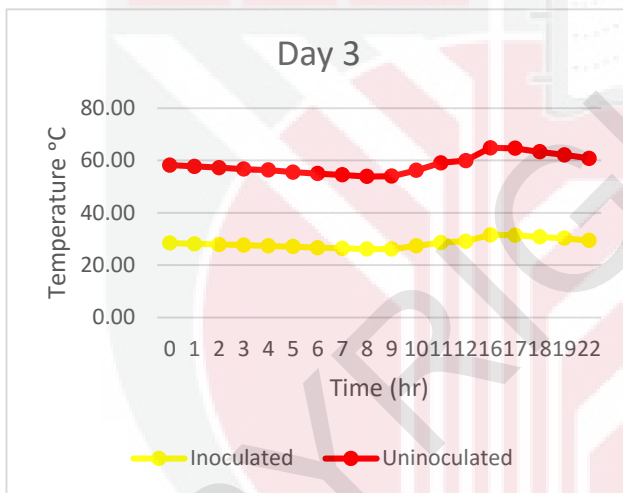
c) Temperature



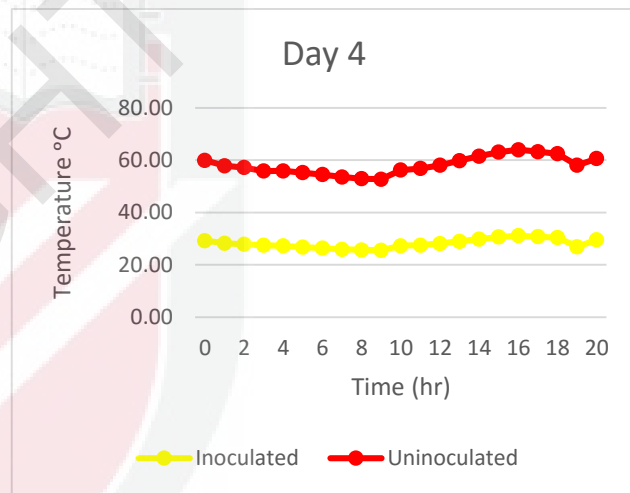
(a)



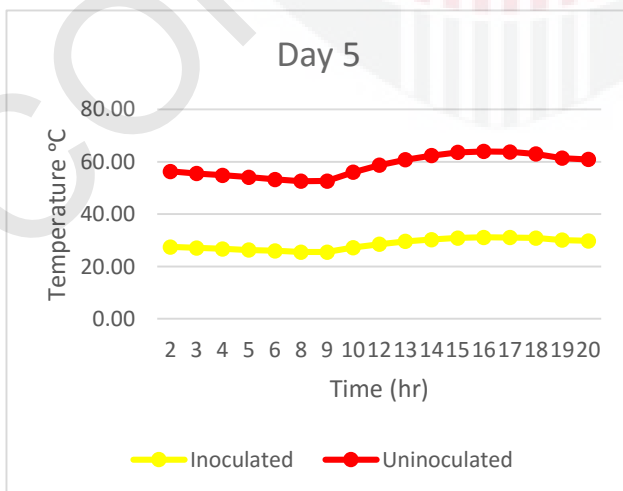
(b)



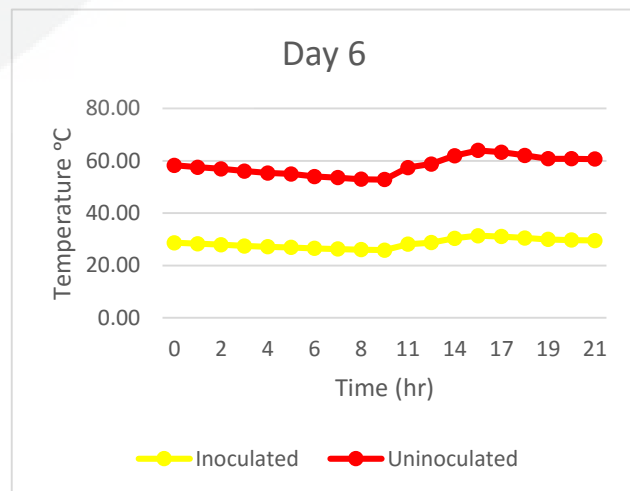
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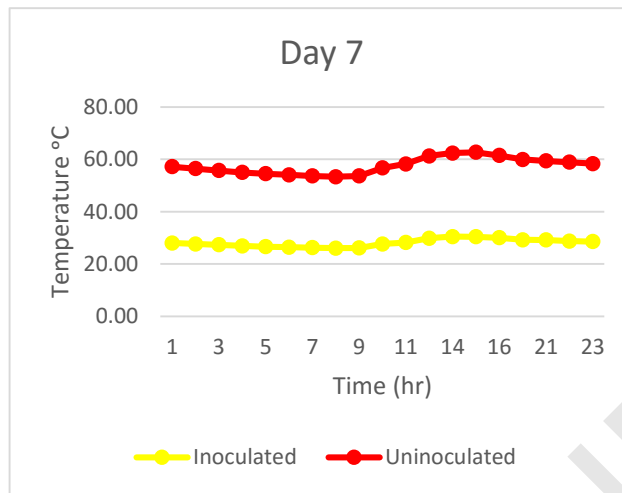
(d)



(e)



(f)



(g)

Figure 16: Average temperature °C of inoculated and uninoculated oil palm seed in Week 3. (a) Day 1. (b) Day 2. (c) Day 3. (d) Day 4. (e) Day 5. (f) Day 6. (g) Day 7.

Based on Figure 16, the temperature between inoculated and uninoculated showed consistent readings. The figure show increase and decrease trend of reading and uninoculated is the higher than inoculated oil palm seeds. The maximum temperature for uninoculated oil palm seeds are in range 32 °C and for inoculated oil palm seeds the maximum temperature are in range 31 °C.

Table 6: Average of temperature in inoculated and uninoculated oil palm seed by time.

No.	Week 1		Week 5		Week 10	
	Inoculated	Uninoculated	Inoculated	Uninoculated	Inoculated	Uninoculated
1	28.25	29.62	27.48	29.54	29.34	29.99
2	27.87	29.35	27.25	29.34	29.09	29.71
3	27.52	28.35	27.02	29.13	28.79	29.28
4	27.22	28.73	26.76	28.94	28.40	28.99
5	26.83	28.44	26.45	28.52	28.02	28.73
6	26.41	28.08	26.13	28.34	27.78	28.50
7	25.96	27.62	25.80	28.12	27.67	28.33
8	25.69	27.25	25.52	27.81	27.30	28.48
9	25.57	27.17	25.57	27.87	27.59	28.48
11	27.52	29.31	27.97	30.31	29.26	30.29
12	28.16	29.89	28.52	30.79	29.97	30.92
13	29.02	30.84	29.34	31.71	30.45	31.55
14	29.85	31.70	30.19	32.56	31.10	32.28
17	30.80	32.44	30.80	33.12	31.67	32.58
19	26.93	31.13	29.70	32.06	30.73	31.72
20	29.55	31.06	29.12	31.51	30.30	31.46

Based on Figure 17, the trend of temperature reading for inoculated are same with uninoculated oil palm seeds. Uninoculated oil palm seed showed the highest temperature on week 7 with 33.12°C and the lower temperature on week 3 with 27.17°C. The maximum temperature for soil properties for inoculated is 32.58°C and its minimum temperature is 25.57°C at week 7.

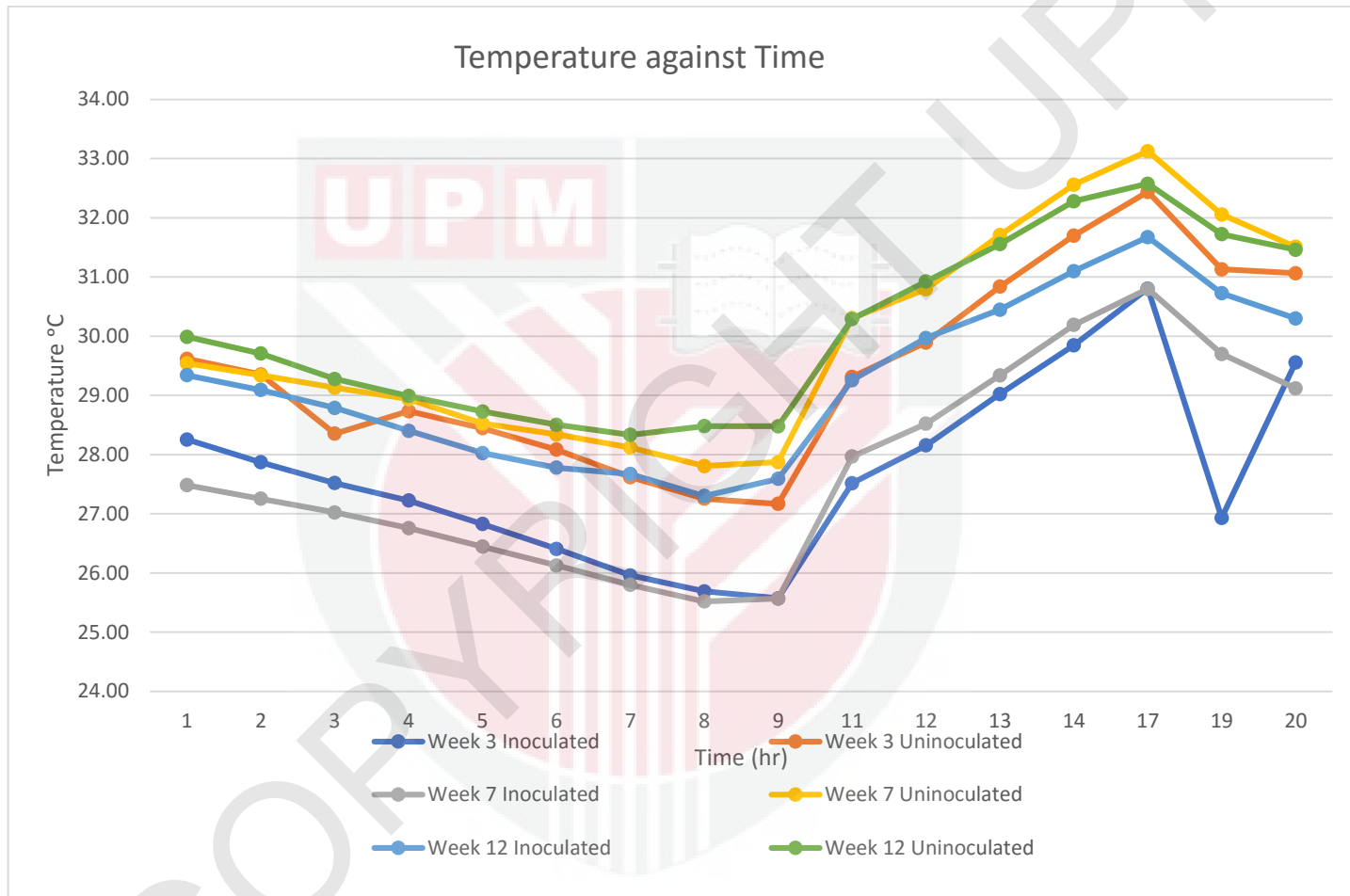


Figure 17: Temperature against time for week 3, 7 and 12.

4.3 Statistical data analysis

Statistical data was analysed using T-test. The data were divided into week, (Week 3, Week 7 and Week 12) and divided into hours. Summary of the T-test result has shown that soil moisture and temperature gave more consistent significant results in differentiating between inoculated and uninoculated oil palm seed except week 7 for soil moisture. (/) represent $P < 0.05$ which has significant different between inoculated and un-inoculated oil palm seed and (X) are not significant difference. At all weeks at 2-4am, 8am and 8pm; and 1-2am, 4am-3pm and 6-10pm, respectively. BSR in oil palm seedling can be detected as early as in week 3 after plant using value of soil moisture content and temperature.

Table 7: Significant difference of soil moisture between inoculated and uninoculated oil palm seed.

Time (hr)	Soil moisture Sig. Different								
	Week 3			Week 7			Week 12		
	Inoculated	Uninoculated	Sig. Diff.	Inoculated	Uninoculated	Sig. Diff.	Inoculated	Uninoculated	Sig. Diff.
0	34.778 ^b	36.310 ^a	/	31.954 ^b	32.611 ^a	X	31.220 ^b	32.110 ^a	/
1	34.996 ^b	36.416 ^a	/	32.100 ^b	32.76 ^a	X	31.237 ^b	32.128 ^a	/
2	34.887 ^b	36.457 ^a	/	31.955 ^b	32.728	X	31.125 ^b	32.043 ^a	/
3	34.847 ^b	36.392 ^a	/	31.941 ^b	32.722 ^a	X	31.294 ^b	32.104 ^a	/
4	34.886 ^b	36.437 ^a	/	31.890 ^b	32.644 ^a	X	31.172 ^b	32.036 ^a	/
5	34.869 ^b	36.369 ^a	/	31.934 ^b	32.691 ^a	X	31.193 ^b	32.089 ^a	/
6	34.798 ^b	36.392 ^a	/	31.928 ^b	32.679 ^a	/	31.202 ^b	32.085 ^a	/
7	34.874 ^b	36.346 ^a	/	31.902 ^b	32.669 ^a	X	31.128 ^b	32.036 ^a	/
8	34.719 ^b	36.295 ^a	/	31.886 ^b	32.678 ^a	/	31.135 ^b	32.002 ^a	/
9	34.704 ^b	36.372 ^a	/	31.940 ^b	32.680 ^a	X	31.133 ^b	32.039 ^a	/
10	35.353 ^b	36.724 ^a	/	33.552 ^b	34.129 ^a	X	34.016 ^b	34.698 ^a	/
11	35.169 ^b	36.695 ^a	/	33.102 ^b	33.613 ^a	X	32.940 ^b	33.643 ^a	/
12	35.034 ^b	36.634 ^a	/	32.817 ^b	33.332 ^a	X	32.569 ^b	33.333 ^a	/
13	34.841 ^b	36.465 ^a	/	32.803 ^b	33.329 ^a	X	32.285 ^b	33.042 ^a	/
14	34.967 ^b	36.42 ^a	/	33.605 ^a	33.168 ^b	X	32.034 ^b	32.817 ^a	/
15	34.779 ^b	36.336 ^a	/	31.590 ^b	32.46 ^a	X	31.818 ^b	32.579 ^a	/
16	34.615 ^b	36.209 ^a	/	32.756 ^b	33.326 ^a	X	31.520 ^b	32.388 ^a	/
17	35.153 ^b	36.566 ^a	/	32.430 ^b	33.015 ^a	X	31.368 ^b	32.284 ^a	/

18	35.060 ^b	36.533 ^a	/	32.037 ^b	32.751 ^a	X	31.243 ^b	32.150 ^a	/
19	34.965 ^b	36.468 ^a	/	31.730 ^b	32.448 ^a	X	31.262 ^b	32.142 ^a	/
20	35.013 ^b	36.517 ^a	/	31.805 ^b	32.521 ^a	/	31.315 ^b	32.168 ^a	/
21	35.075 ^b	36.548 ^a	/	32.213 ^b	32.792 ^a	X	31.372 ^b	32.154 ^a	/
22	34.811 ^b	36.484 ^a	/	32.241 ^b	32.964 ^a	X	31.207 ^b	32.030 ^a	/
23	34.932 ^b	36.471 ^a	/	31.963 ^b	32.578 ^a	X	31.28 ^b	32.137 ^a	/

(X^a) = value is higher; (X^b) = value is lower.

Table 7 showed the significant difference between inoculated and uninoculated oil palm seed for moisture content and week 3 and week 12 give more consistent result than week 5. This is mean that BSR can be detected as early in week 3 after planting using value soil moisture content. For discussion, the moisture content of soil can be affected by BSR in root and based on the result value, it showed that uninoculated is higher than inoculated oil palm seed for every week.

Table 8: Significant difference of electrical-conductivity between inoculated and uninoculated oil palm seed.

Time (hr)	EC Sig. Different								
	Week 3			Week 7			Week 12		
	Inoculated	Uninoculated	Sig. Diff.	Inoculated	Uninoculated	Sig. Diff.	Inoculated	Uninoculated	Sig. Diff.
0	111.092 ^b	137.688 ^a	/	178.725 ^b	201.925 ^a	X	144.283 ^b	155.669 ^a	X
1	110.650 ^b	136.990 ^a	/	167.060 ^b	188.897 ^a	X	148.020 ^b	161.224 ^a	X
2	110.003 ^b	137.122 ^a	/	165.107 ^b	190.193 ^a	X	140.172 ^b	151.014 ^a	X
3	110.056 ^b	137.806 ^a	/	165.650 ^b	190.223 ^a	X	149.174 ^b	162.280 ^a	X
4	110.514 ^b	137.942 ^a	/	168.950 ^b	193.983 ^a	X	155.753 ^b	169.930 ^a	X
5	110.643 ^b	135.237 ^a	/	166.917 ^b	192.223 ^a	X	146.344 ^b	163.917 ^a	X
6	112.142 ^b	139.275 ^a	/	167.987 ^b	192.777 ^a	X	148.469 ^b	164.288 ^a	X
7	111.554 ^b	137.088 ^a	/	168.567 ^b	194.292 ^a	X	149.514 ^b	164.089 ^a	X
8	113.490 ^b	142.486 ^a	/	168.540 ^b	193.983 ^a	X	149.300 ^b	163.790 ^a	X
9	113.248 ^b	140.860 ^a	/	167.500 ^b	192.330 ^a	X	147.987 ^b	162.355 ^a	X
10	97.370 ^b	112.011 ^a	/	140.688 ^b	160.071 ^a	X	130.451 ^a	122.681 ^b	X
11	99.322 ^b	124.950 ^a	/	156.122 ^b	173.244 ^a	X	113.067 ^b	118.875 ^a	X
12	104.713 ^b	128.390 ^a	/	161.717 ^b	181.844 ^a	X	123.125 ^b	132.015 ^a	X
13	108.750 ^b	136.953 ^a	/	155.379 ^b	180.633 ^a	X	132.911 ^b	140.802 ^a	X
14	111.753 ^b	138.593 ^a	/	168.321 ^b	188.400 ^a	X	137.512 ^b	148.993 ^a	X
15	116.863 ^b	144.317 ^a	/	178.430 ^b	205.270 ^a	X	141.071 ^b	153.346 ^a	X
16	114.821 ^b	144.898 ^a	/	159.608 ^b	180.258	X	144.942 ^b	153.962 ^a	X
17	94.493 ^b	116.530 ^a	/	167.578 ^b	192.683 ^a	X	142.211 ^b	152.638 ^a	X
18	99.186 ^b	125.053 ^a	/	165.538 ^b	189.929 ^a	X	139.781 ^b	146.988 ^a	X
19	101.277 ^b	125.290 ^a	/	176.450 ^b	199.489 ^a	X	135.513 ^b	142.290 ^a	X
20	101.839 ^b	127.844 ^a	/	171.554 ^b	195.013 ^a	X	136.922 ^b	144.625 ^a	X
21	103.317 ^b	129.117 ^a	/	154.544 ^b	176.183 ^a	X	138.557 ^b	145.710 ^a	X
22	105.522 ^b	133.072 ^a	/	165.306 ^b	187.861 ^a	X	141.129 ^b	150.524 ^a	X
23	106.428 ^b	134.933 ^a	/	174.300 ^b	191.567 ^a	X	135.538 ^b	144.342 ^a	X

(X^a) = value is higher; (X^b) = value is lower.

Table 8 showed the significant difference between inoculated and uninoculated oil palm seed for electrical conductivity and the result was not consistent for week 5 and 12. Based on my observation, the not consistent result because of the high moisture content and fertilizer clump at sensor area. Based on the result value, it showed that uninoculated is higher than inoculated oil palm seed for every week.

Table 9: Significant difference of temperature between inoculated and uninoculated oil palm seed.

Time (hr)	Temperature Sig. Different								
	Week 3			Week 7			Week 12		
	Inoculated	Uninoculated	Sig. Diff.	Inoculated	Uninoculated	Sig. Diff.	Inoculated	Uninoculated	Sig. Diff.
0	28.893 ^b	30.112	/	27.701 ^b	30.182 ^a	X	29.383 ^b	30.053 ^a	/
1	28.306 ^b	29.540 ^a	/	27.691 ^b	29.426 ^a	/	29.105 ^b	29.795 ^a	/
2	27.888 ^b	29.126 ^a	/	27.282 ^b	29.251 ^a	/	29.039 ^b	29.667 ^a	/
3	27.547 ^b	28.709 ^a	/	26.986 ^b	28.820 ^a	/	28.674 ^b	29.294 ^a	X
4	27.261 ^b	28.561 ^a	/	26.553 ^b	28.680 ^a	/	28.129 ^b	28.970 ^a	/
5	26.849 ^b	28.218 ^a	/	26.414 ^b	28.456 ^a	/	28.138 ^b	28.999 ^a	/
6	26.656 ^b	27.880 ^a	/	26.105 ^b	28.029 ^a	/	27.948 ^b	28.717 ^a	/
7	26.350 ^b	27.699 ^a	/	25.982 ^b	28.036 ^a	/	27.752 ^b	28.542 ^a	/
8	26.162 ^b	27.498 ^a	/	25.559 ^b	27.661 ^a	/	27.627 ^b	28.442 ^a	/
9	26.242 ^b	27.552 ^a	/	25.654 ^b	27.681 ^a	/	27.872 ^b	28.691 ^a	/
10	27.542 ^b	28.968 ^a	/	26.750 ^b	28.849 ^a	/	28.721 ^b	29.822 ^a	/
11	28.405 ^b	29.921 ^a	/	28.198 ^b	30.252 ^a	/	29.276 ^b	30.255 ^a	/
12	28.902 ^b	30.51 ^a	/	28.613 ^b	30.845 ^a	/	29.752 ^b	30.823 ^a	/
13	30.132 ^b	31.698 ^a	/	29.441 ^b	31.474 ^a	/	30.322 ^b	31.46 ^a	/
14	30.656 ^b	32.164 ^a	/	30.588 ^b	32.736 ^a	/	30.812 ^b	31.97 ^a	/
15	31.372 ^b	33.012 ^a	/	32.070 ^b	34.100 ^a	X	31.105 ^b	32.19 ^a	/
16	31.626 ^b	33.069 ^a	/	29.932 ^b	32.051 ^a	X	31.162 ^b	32.179 ^a	/
17	31.403 ^b	32.925 ^a	/	30.089 ^b	32.222 ^a	/	30.984 ^b	31.916 ^a	X
18	31.049 ^b	32.483 ^a	/	30.677 ^b	32.695 ^a	/	31.811 ^a	31.727 ^b	/
19	29.784 ^b	31.641 ^a	X	29.750 ^b	31.789 ^a	/	30.545 ^b	31.459 ^a	/
20	29.886 ^b	31.283 ^a	/	29.183 ^b	31.325 ^a	/	30.204 ^b	31.155 ^a	/
21	29.766 ^b	31.046 ^a	X	28.667 ^b	30.676 ^a	/	29.910 ^b	30.744 ^a	/
22	29.481 ^b	30.819 ^a	X	28.304 ^b	30.502 ^a	/	29.856 ^b	30.680 ^a	/
23	29.059 ^b	30.277 ^a	X	28.709 ^b	30.534 ^a	X	29.577 ^b	30.304 ^a	/

(X^a) = value is higher; (X^b) = value is lower.

Table 9 showed the significant difference between inoculated and uninoculated oil palm seed for temperature and the result were consistent for every weeks. It mean that the value of temperature can be used to detect BSR in oil palm seedling as early as in week 3 and based on the value result, it showed that uninoculated is higher than inoculated oil palm seed for every week.

Chapter 5 Conclusion and Recommendation

This study was focusing on the monitor soil properties of inoculated and uninoculated Basal Stem Rot (BSR) in oil palm seeding. Soil properties namely soil moisture, electrical-conductivity and temperature. There are three objectives that have been specified in this study and successfully obtained.

Objective one is to determine the trend of soil properties taken from three different equipment include MEC10 sensor. Equipment used for soil moisture measurement were TDR 100 and MEC10 sensor, while Panasonic temperature, soil thermometer and MEC10 were used for temperature measurement. For electrical conductivity, equipment of MEC10, Land Mapper and EC probe. It can be conclude that MEC10 is sensor which can measure three parameters in soil namely moisture content, temperature and EC give same trend of reading as other equipment. MEC10 can be used for any type of plant and anywhere as we can collect the data using internet.

Based on objective 2, which is to monitor moisture content, electrical conductivity and temperature of soil in inoculated and un-inoculated oil palm seed, there's no standard trend over time for all parameters. However, all parameters gave higher value at uninoculated sample compared to inoculated sample.

Objective 3 is to analyse the statistical data of soil properties on the soil properties of inoculate and un-inoculated oil palm seed. It can be conclude that soil moisture and temperature gave more consistent significant results in differentiating between inoculated and uninoculated oil palm seed at all weeks at 8am and 8pm respectively. BSR in oil palm seedling can be detected as early as in week 3 after plant using value of soil moisture content and temperature.

For recommendation, the research can be extended to detect and monitor the BSR at the plantation area. By extend the time, further research about *ganoderma* growth can

be done and discussion about monitor and control BSR can be made. From this experiment, we can applied this to industry to minimize the loss of oil palm by analyse the growth of *ganoderma* during nursery stage.



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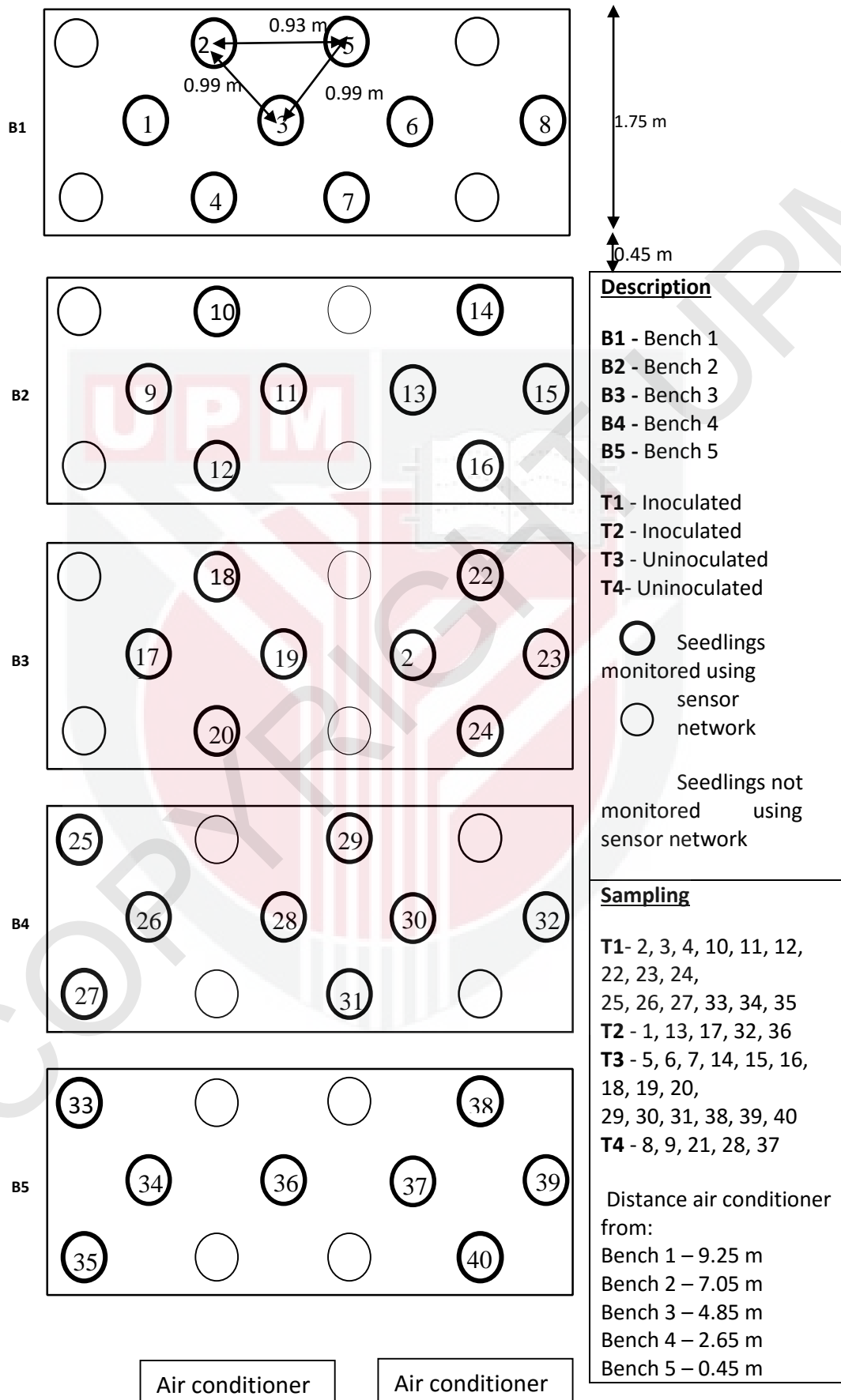
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Appendices

Appendix A: Position and layout of oil palm seeds.

Seedling	Sensor	Seedling	Sensor
1	1,2,3	21	61,62,63
2	4,5,6	22	64,65,66
3	7,8,9	23	67,68,69
4	10,11,12	24	70,71,72
5	13,14,15	25	73,74,75
6	16,17,18	26	76,77,78
7	19,20,21	27	79,80,81
8	22,23,24	28	82,83,84
9	25,26,27	29	85,86,87
10	28,29,30	30	88,89,90
11	31,32,33	31	91,92,93
12	34,35,36	32	94,95,96
13	37,38,39	33	97,98,99
14	40,41,42,	34	100,101,102
15	43,44,45	35	103,104,105
16	46,47,48	36	106,107,108
17	49,50,51	37	109,110,111
18	52,53,54	38	112,113,114
19	55,56,57	39	115,116,117
20	58,59,60	40	118,119,120



Appendix B: Data analysis of soil properties monitoring for Week 7 and Week 12.

a) Soil moisture

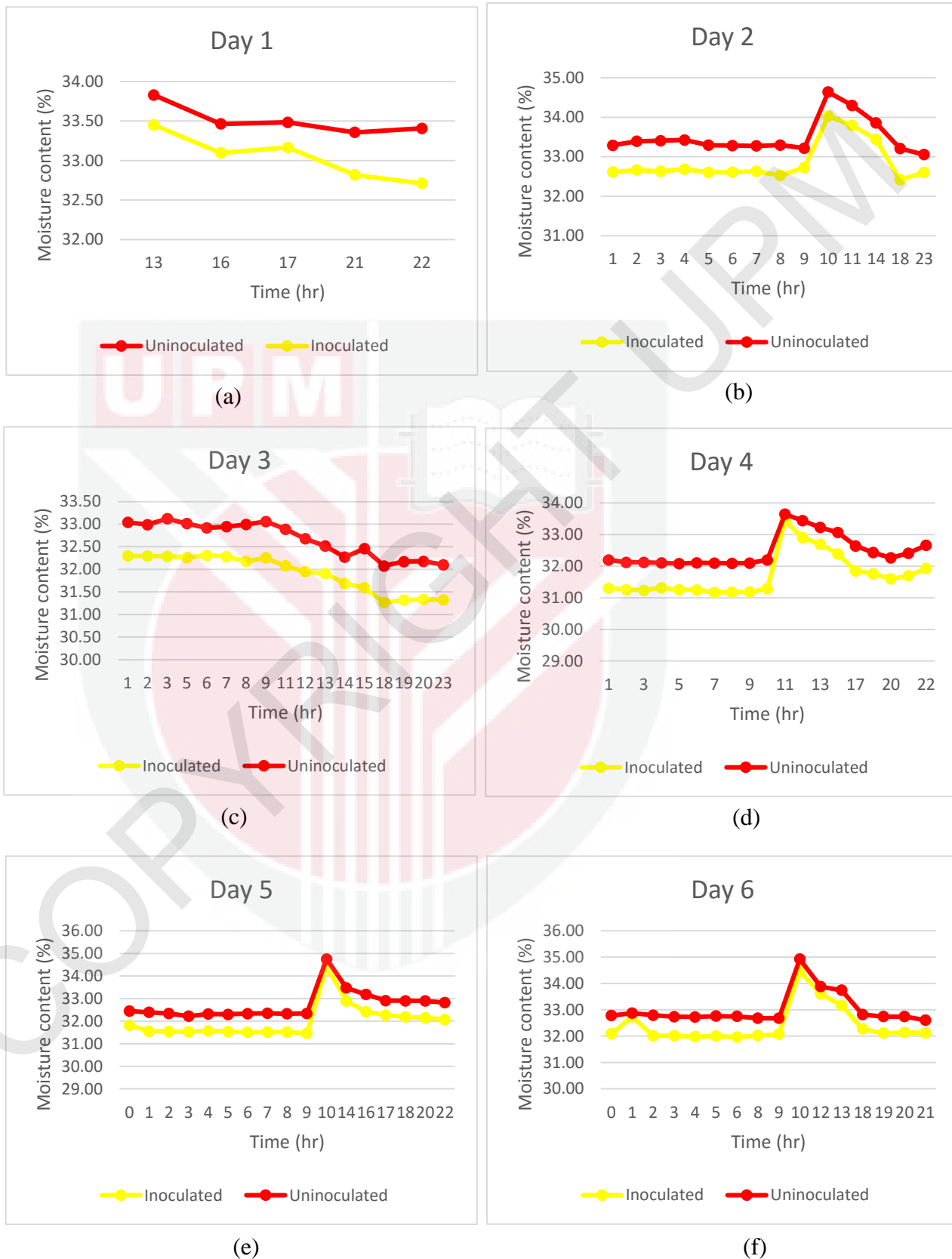
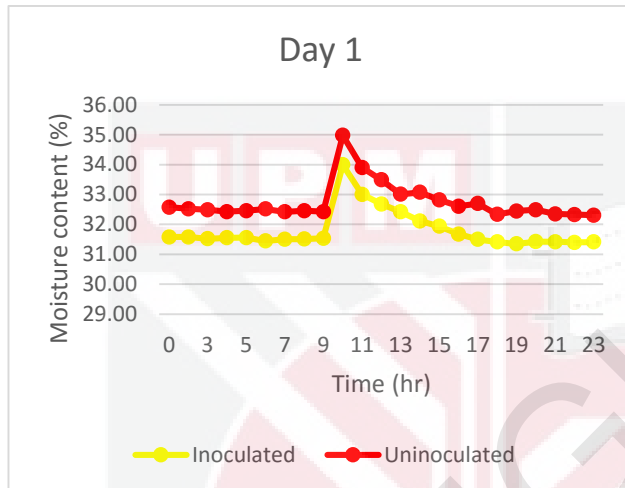
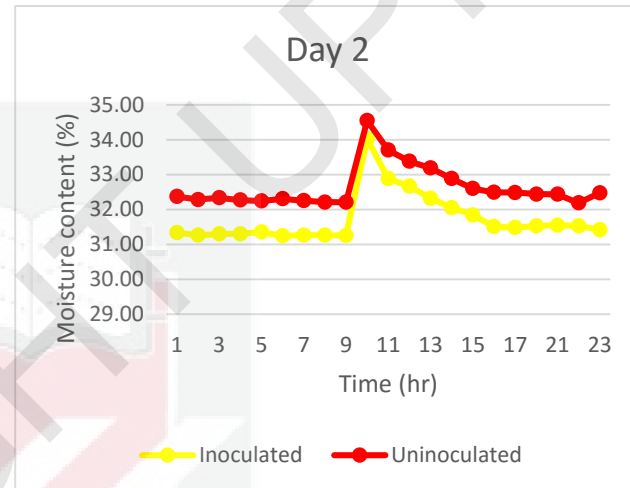


Figure 18: Average moisture content (%) of inoculated and uninoculated of oil palm seed in Week 7. (a) Day 1. (b) Day 2. (c) Day 3. (d) Day 4. (e) Day 5. (f) Day 6.

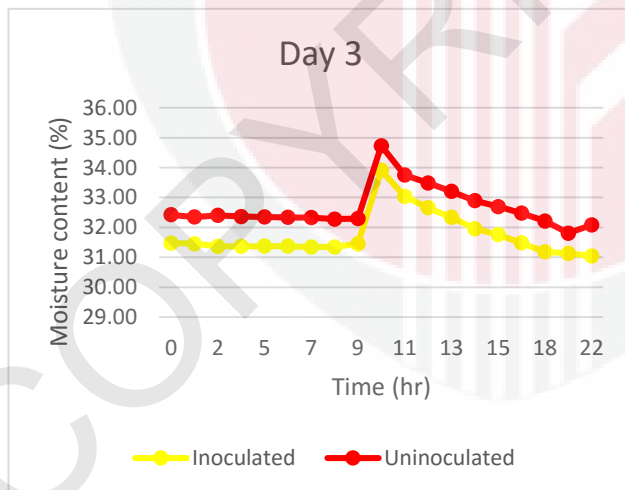
Based on Figure 18, week 7, moisture content for both type of sample showed the un-consistent result by day. For day 1 and 3, the moisture content decrease by time, while, day 2, 4, 5 and 6 the moisture content for inoculated and un-inoculated are consistent by time.



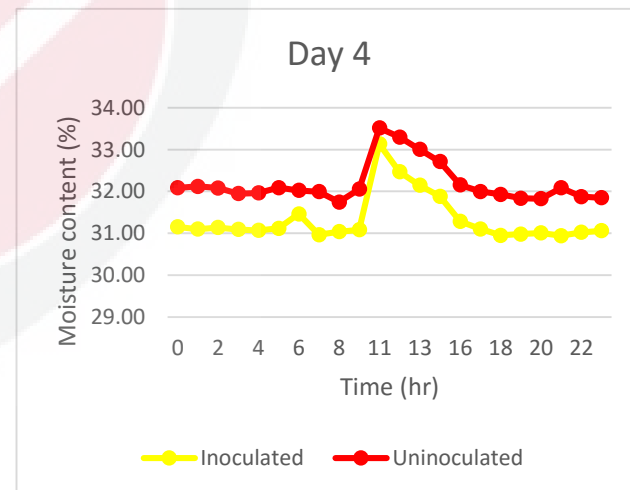
(a)



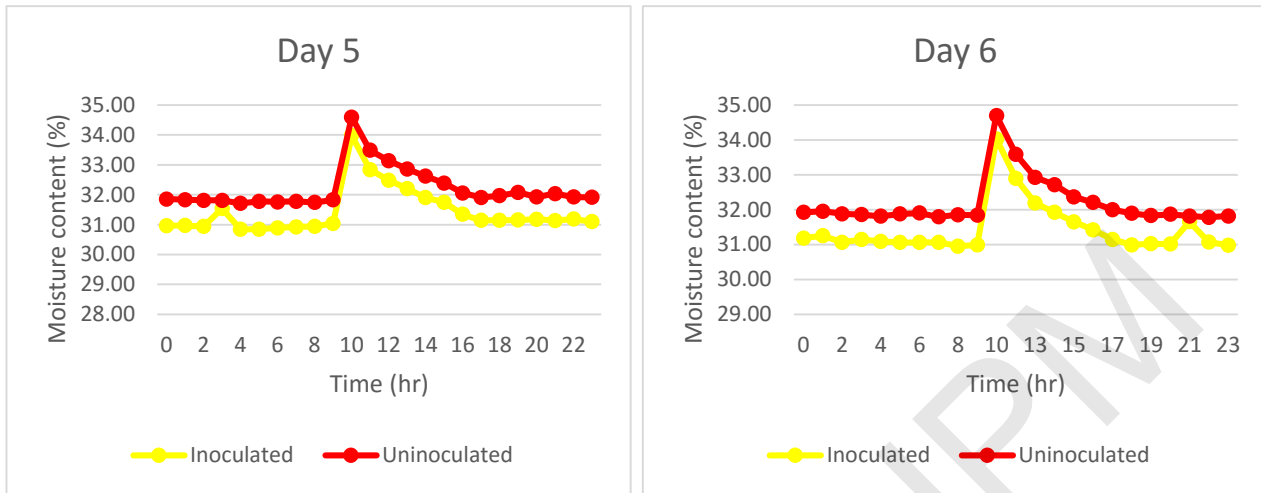
(b)



(c)

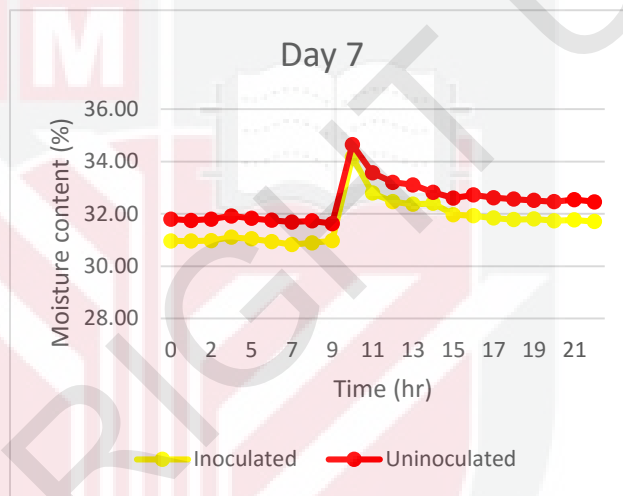


(d)



(e)

(f)



(g)

Figure 19: Average moisture content (%) of inoculated and uninoculated of oil palm seed in Week 12. (a) Day 1. (b) Day 2. (c) Day 3. (d) Day 4. (e) Day 5. (f) Day 6. (g) Day 7.

Based on figure 19, week 12, moisture content for both sample showed the consistent result for every 7 days. Moisture content increase suddenly at time 11 am because of the watering time.

b) Electrical-conductivity

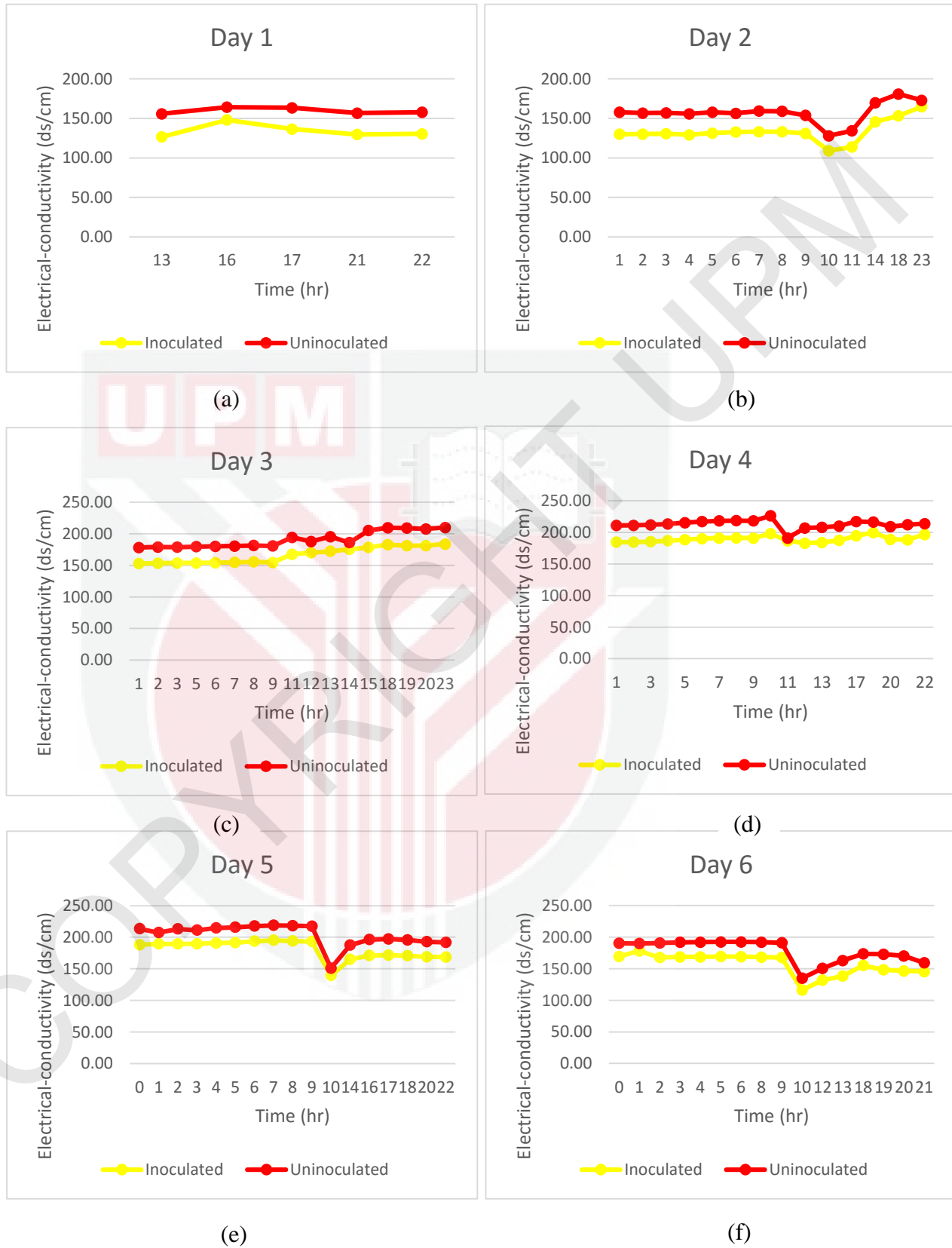
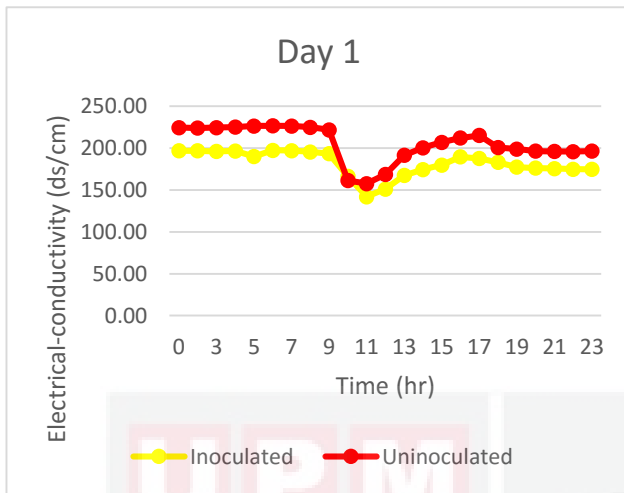
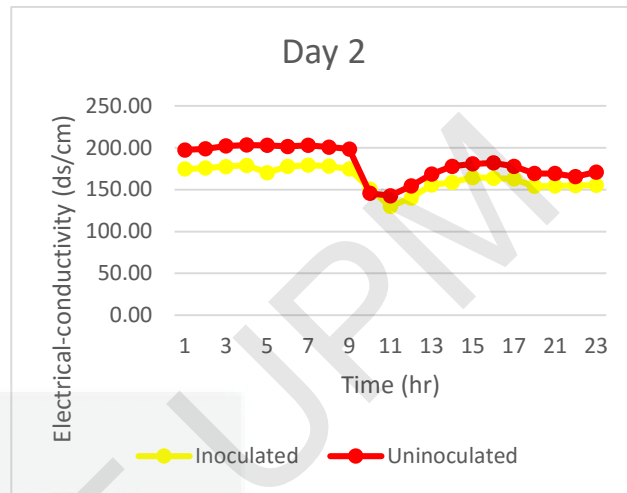


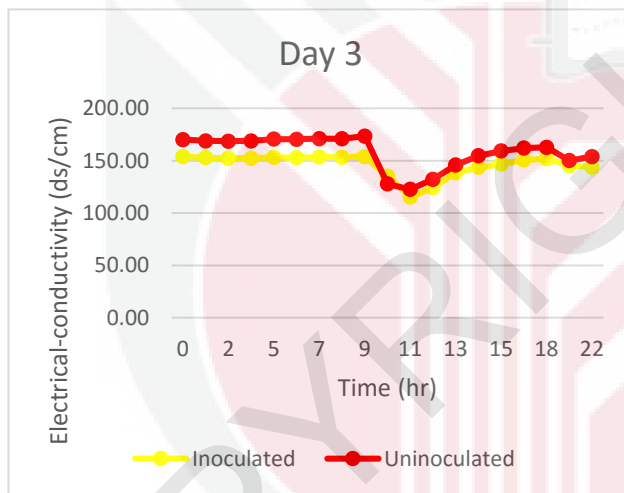
Figure 20: Average electrical-conductivity (EC) ds/cm of inoculated and uninoculated oil palm seed in Week 7. (a) Day 1. (b) Day 2. (c) Day 3. (d) Day 4. (e) Day 5. (f) Day 6.



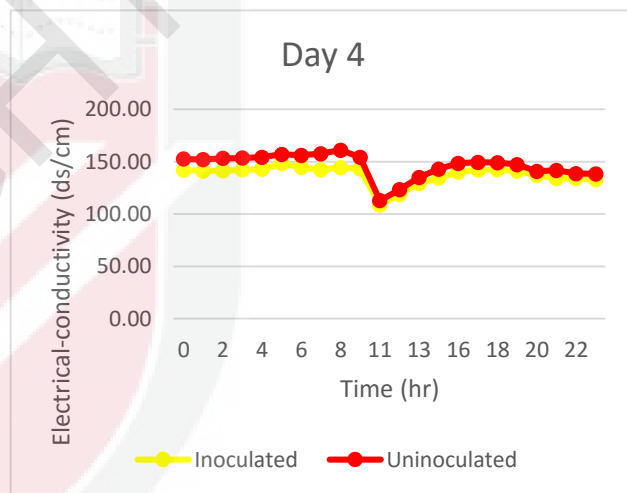
(a)



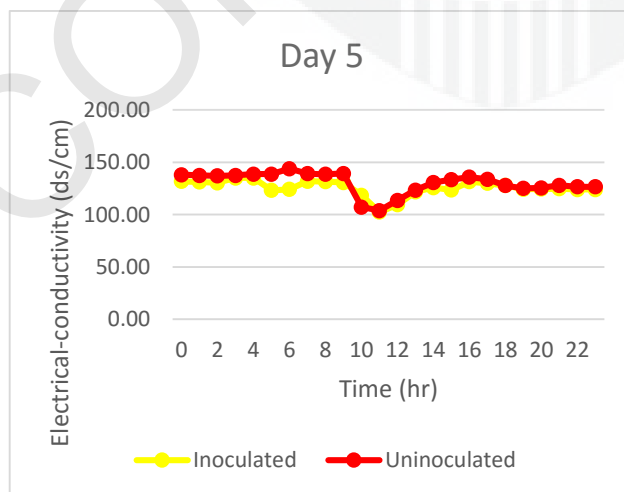
(b)



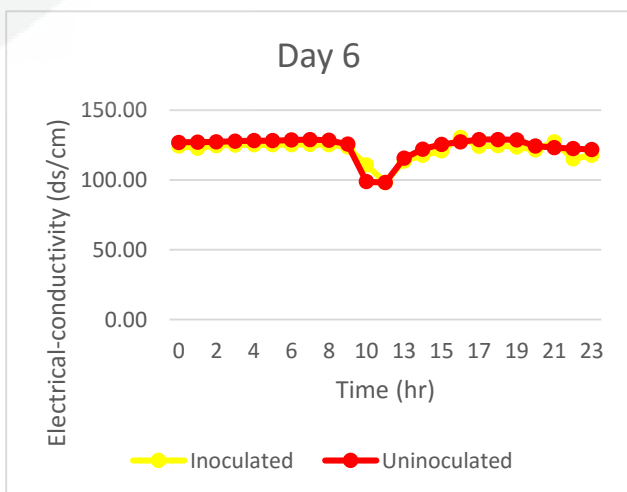
(c)



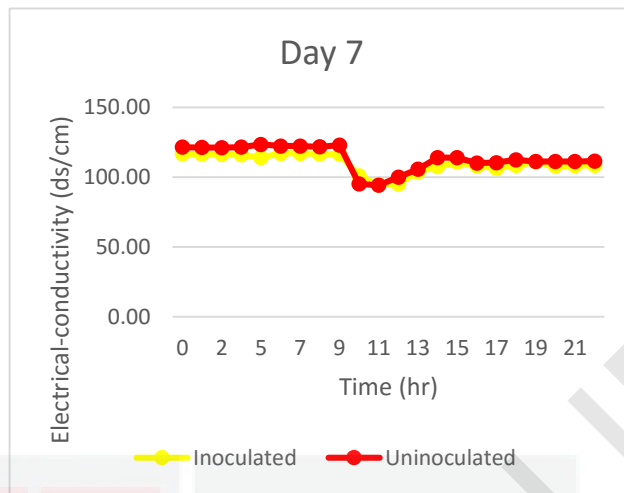
(d)



(e)



(f)

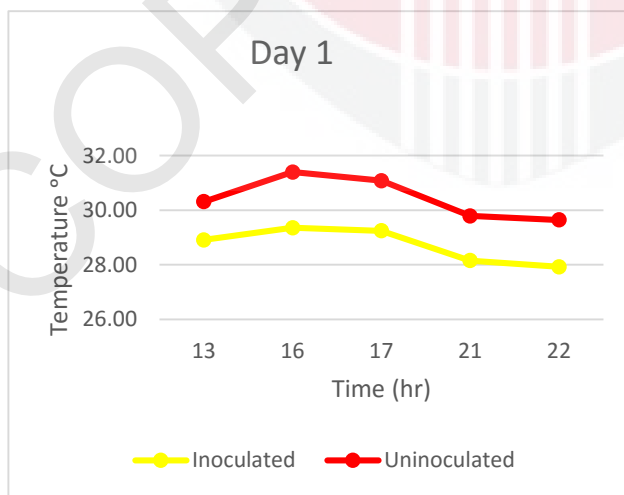


(g)

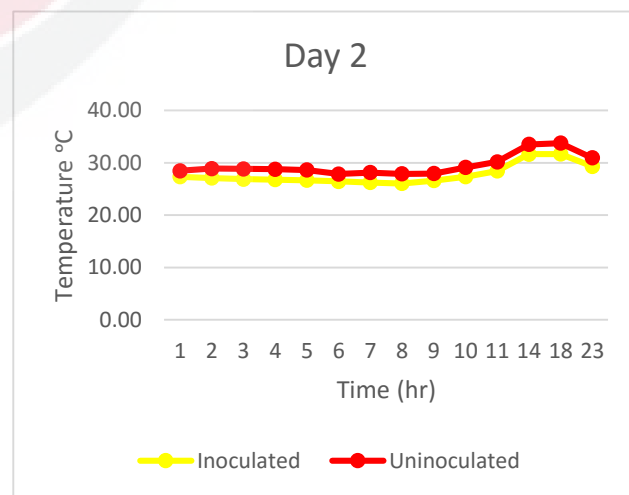
Figure 21: Average electrical-conductivity (EC) ds/cm of inoculated and uninoculated oil palm seed in Week 12. (a) Day 1. (b) Day 2. (c) Day 3. (d) Day 4. (e) Day 5. (f) Day 6. (g) Day 7.

Based on Figure 20 and 21, there are small difference of EC between inoculated and uninoculated oil palm seeds. Both given same trend with range 150 ds/cm to 250 ds/cm.

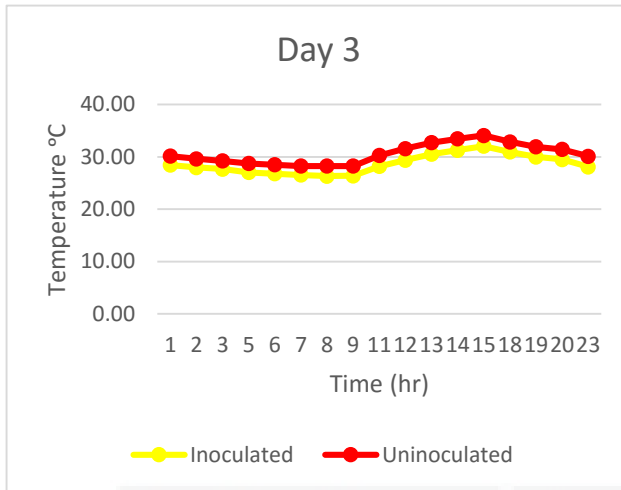
c) Temperature



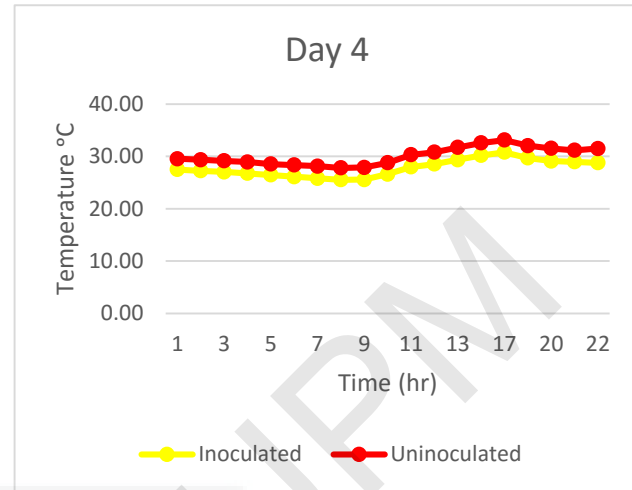
(a)



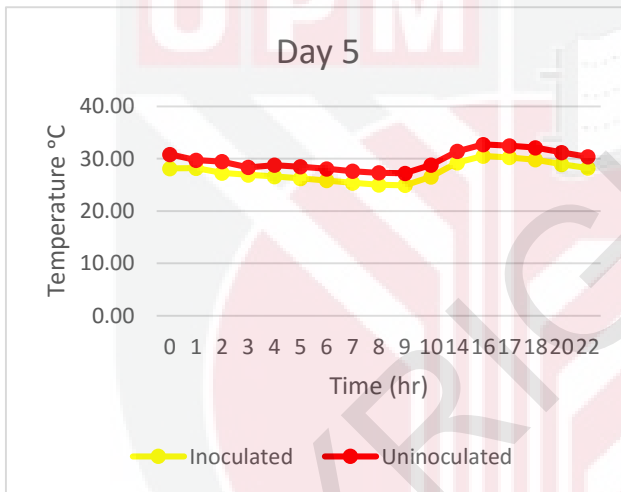
(b)



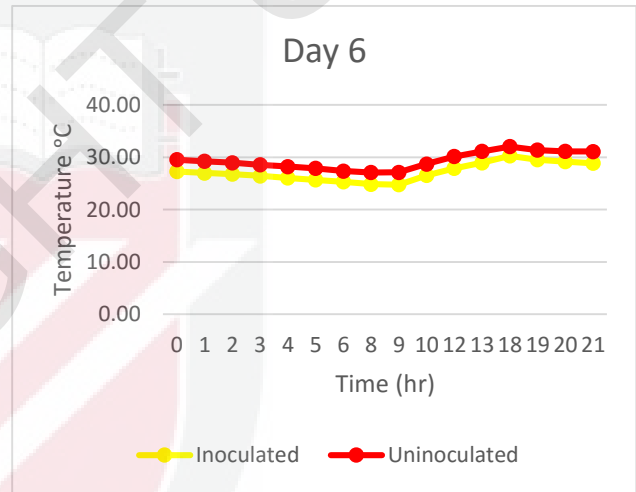
(c)



(d)

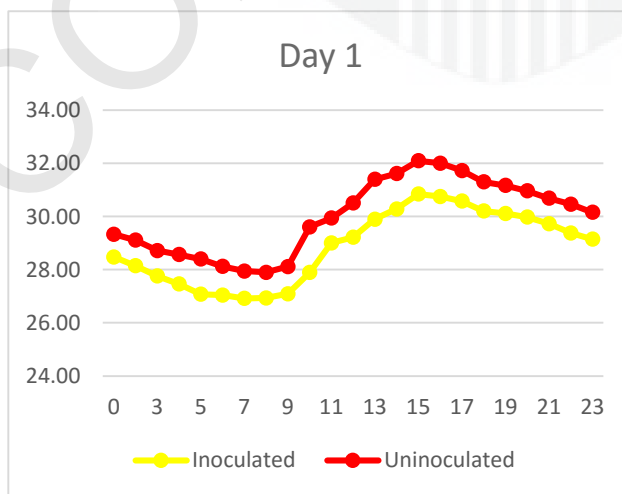


(e)

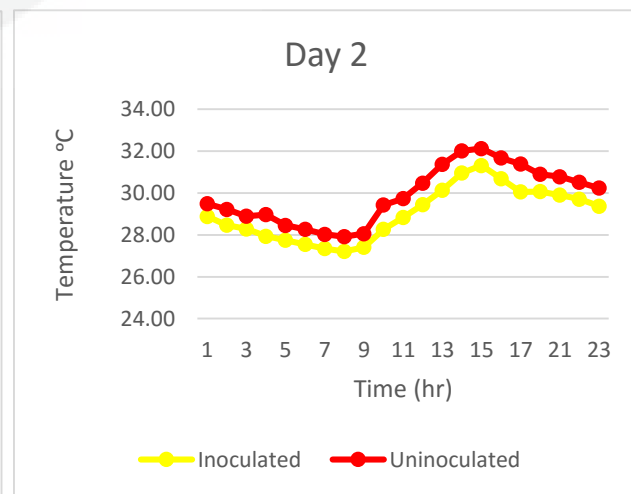


(f)

Figure 22: Average temperature °C of inoculated and uninoculated oil palm seed in Week 7. (a) Day 1. (b) Day 2. (c) Day 3. (d) Day 4. (e) Day 5. (f) Day 6.



(a)



(b)

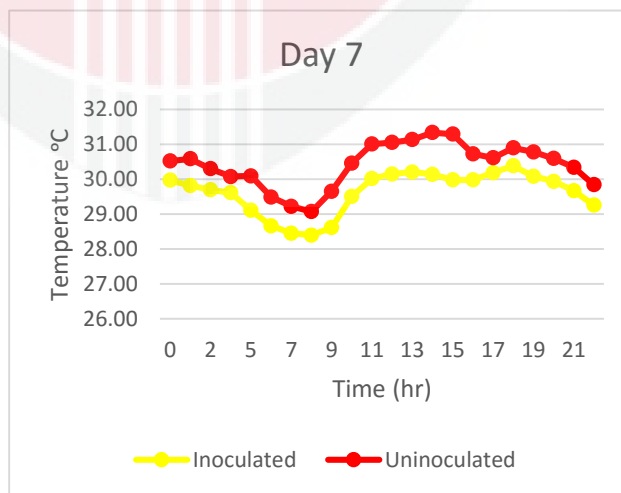
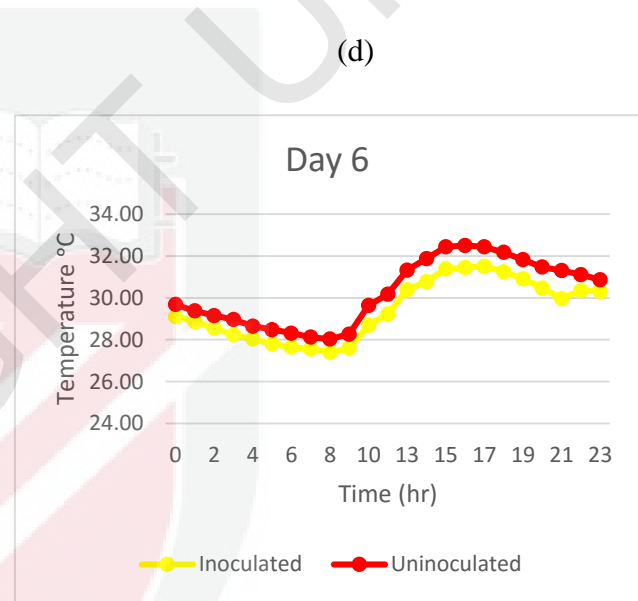
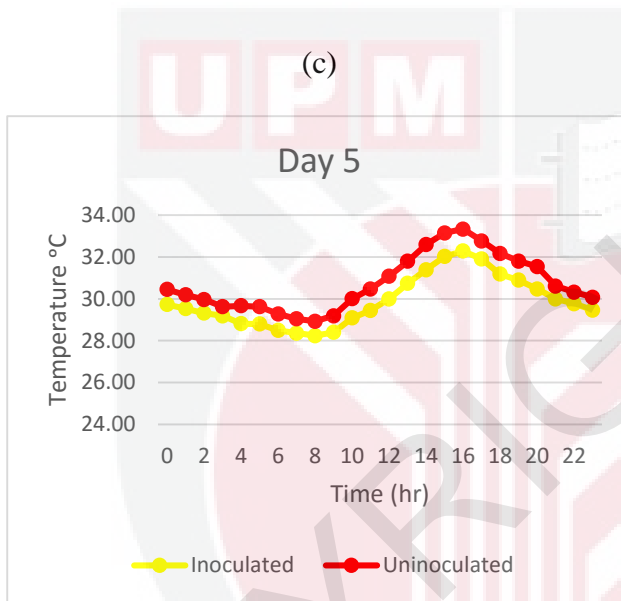
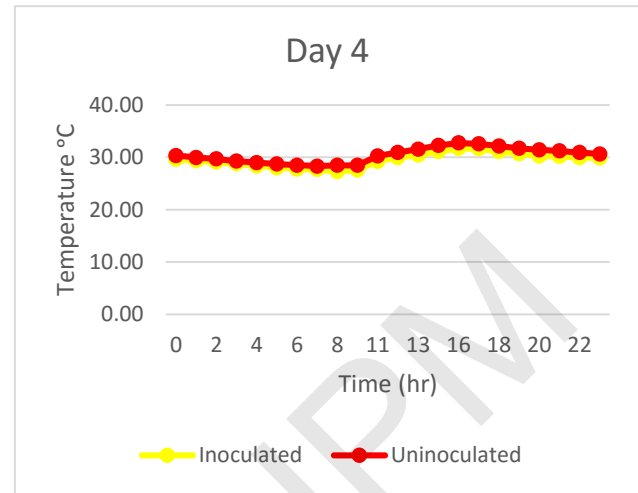
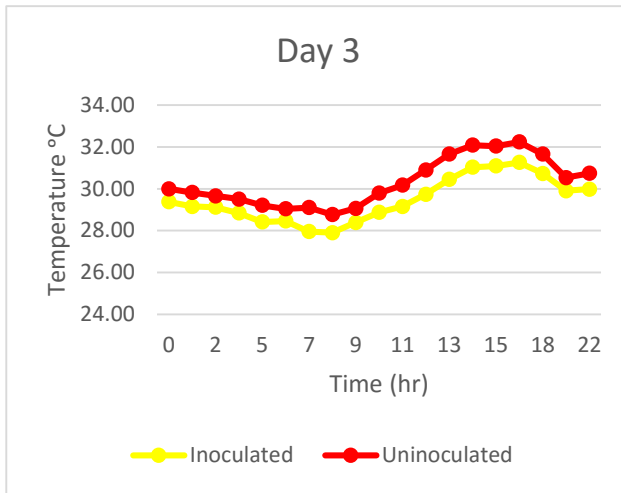


Figure 23: Average temperature °C of inoculated and uninoculated oil palm seed in Week 12. (a) Day 1. (b) Day 2. (c) Day 3. (d) Day 4. (e) Day 5. (f) Day 6. (g) Day 7.

Appendix C: Example of Statistical Data Analysis by T-Test

Week 3 (Soil moisture)

t-Test: Two-Sample Assuming Unequal Variances (0)

	<i>Inoculated</i>	<i>Uninoculated</i>
Mean	34.77758333	36.399875
Variance	0.075990157	0.016299933
Observations	4	4
Hypothesized Mean Difference	0	
df	4	
t Stat	-10.68024948	
P(T<=t) one-tail	0.000217686	
t Critical one-tail	2.131846786	
P(T<=t) two-tail	0.000435372	
t Critical two-tail	2.776445105	

Week 3 (Electrical-conductivity)

t-Test: Two-Sample Assuming Unequal Variances (0)

	<i>Inoculated</i>	<i>Uninoculated</i>
Mean	111.0916667	137.6875
Variance	21.97601852	58.04988426
Observations	4	4
Hypothesized Mean Difference	0	
df	5	
t Stat	-5.946046584	
P(T<=t) one-tail	0.000961111	
t Critical one-tail	2.015048373	
P(T<=t) two-tail	0.001922222	
t Critical two-tail	2.570581836	

Week 3 (Temperature)

t-Test: Two-Sample Assuming Unequal Variances (0)

	<i>Inoculated</i>	<i>Uninoculated</i>
Mean	28.89291832	30.1117129
Variance	0.223178185	0.398455562
Observations	5	5
Hypothesized Mean Difference	0	
df	7	
t Stat	-3.456592836	
P(T<=t) one-tail	0.005298154	
t Critical one-tail	1.894578605	
P(T<=t) two-tail	0.010596308	
t Critical two-tail	2.364624252	