EFFICACY OF COCO PEAT MULCH TREATED WITH WOOD VINEGAR ON CONTROL WOODY BORRERIA (*Hedyotis verticillata* (L.) LAM.) AT THE VEGETATIVE STAGE

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DECLARATION

I hereby declare that the work embodied in this report embodied in this report is the result of the original research and has not been submitted for a higher degree to any universities or institutions.

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Date : 26 JANUARY 2022

I certify that the report of this final year project entitled "Efficacy of Coco Peat Mulch Treated with Wood Vinegar on Control Woody Borreria (*Hedyotis verticillata* (L.) Lam.) at the Vegetative Stage" by Adlin Farhanah Binti Mohd Azmi, matric number F18B0005 has been examined and all the correction recommended by examiners have been done for the degree of Bachelor of Applied Science Agrotechnology with Honours, Faculty of Agro-Based Industry, University Malaysia Kelantan.

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Efficacy of Coco Peat Mulch Treated with Wood Vinegar on Control Woody Borreria (*Hedyotis verticillata* (L.) Lam.) at the Vegetative Stage

ABSTRACT

In Malaysia, The National Agro-Food Policy (NAFP 2011-2020) has brought focus on improving the farmer's income through the implementation of precision weed control methods to reduce uncertainties that related to managing variabilities in farm. Recently, mulching and herbicide application is a promising approach to reduce weed infestation, however there is limited literature on combined effect of mulching with natural plant products. Therefore, a study was carried out to determine the effect of different application rates of coco peat mulch treated with wood vinegar on the emergence and growth performance of woody borreria weed (*Hedyotis verticillata* (L.) Lam.) at the vegetative stage. The woody borreria was treated with different application rate of coco peat mulch at 4 t ha^{-1}, 8 t ha^{-1} and 12 t ha^{-1}; and wood vinegar at 10%, 20% and 30%. The weed emergence, root length and shoot fresh weight of tested weed species were measured and data obtained was expressed as percentage of control (% of control). The weed emergence was completely inhibited by 100% when the bioassay species were treated at 8 t ha^{-1} coco peat mulch + 30% wood vinegar **(T6).** At this application rate, a similar trend of inhibition was also observed for shoot fresh weight and root length. There was significant reduction on the shoot fresh weight of *H. verticillata* starting from 4 t ha^{-1} - 12 t ha^{-1} coco peat mulch with the wood vinegar concentration ranging from 10% - 30% (**T3, T4, T6, T7, T8,** and **T9**). At these application rates, the shoot fresh weight of the bioassay species was strongly inhibited by 82-100% ($p<0.05$). Though no significance difference were detected at the lower application of coco peat mulch at 4 t ha^{-1} (**T1, T2** and **T3**) as compared to the control, these application rates show strong root reduction with the value ranging from 62%-92% inhibition. These results suggest that the integration of wood vinegar with mulching according to the specific rates had provide optimum control of *H. verticillata*, thus highlighting its potential as a promising weed control method in relation to precise weed management.

Keyword: *Hedyotis verticillata*, wood vinegar, coco peat mulch, inhibition.

Keberkesanan Sungkupan Sabut Kelapa yang dirawat dengan Cuka Kayu terhadap Kawalan Woody Borreria (*Hedyotis verticillata* (L.) Lam.) pada Peringkat Vegetatif

ABSTRAK

Di Malaysia, Dasar Agro-Makanan Negara (NAFP 2011-2020) telah memfokuskan kepada peningkatan pendapatan petani melalui pelaksanaan kaedah kawalan rumpai secara jitu untuk mengurangkan ketidakpastian berhubung dengan pengurusan kebolehubahan dalam ladang. Kebelakangan ini, penggunaan sungkupan dan racun herba merupakan pendekatan yang berpotensi untuk mengurangkan serangan rumpai, walaubagaimanapun literatur tentang kesan gabungan sungkupan dengan produk tumbuhan semula jadi adalah terhad. Oleh itu, satu kajian telah dijalankan untuk menentukan kesan kadar aplikasi sungkupan sabut kelapa berbeza yang dirawat dengan cuka kayu terhadap kemunculan dan prestasi pertumbuhan woody borreria (*Hedyotis verticillata* (L.) Lam.) pada peringkat vegetatif. Woody borreria telah dirawat dengan kadar penggunaan sungkupan sabut kelapa yang berbeza pada 4 t ha-$^{-1}$, 8 t ha^{-1} dan 12 t ha^{-1}; dan cuka kayu pada 10%, 20% dan 30%. Kemunculan rumpai, panjang akar dan berat segar pucuk bagi spesies rumpai yang diuji kemudiannya diukur dan data yang diperoleh dinyatakan sebagai peratusan kawalan (% kawalan). Kemunculan rumpai telah dihalang sepenuhnya sebanyak 100% apabila spesies bioassai dirawat pada sungkupan 8 t ha^{-1} sabut kelapa + 30% cuka kayu **(T6).** Pada kadar aplikasi ini, trend perencatan yang sama juga diperhatikan untuk berat segar pucuk dan panjang akar. Terdapat penurunan yang signifikan pada berat segar pucuk *H. verticillata* bermula daripada sungkupan coco peat 4 t ha^{-1} - 12 t ha^{-1} dengan kepekatan cuka kayu antara 10% - 30% **(T3, T4, T6, T7, T8,** dan **T9).** Pada kadar aplikasi ini, berat segar pucuk spesies bioassai telah direncatkan dengan kuat sebanyak 82-100% ($p<0.05$). Walaupun tiada perbezaan signifikan dikesan pada penggunaan sungkupan sabut kelapa yang lebih rendah pada 4 t ha^{-1} **(T1, T2** dan **T3)** berbanding kawalan, kadar aplikasi ini menunjukkan pengurangan akar yang kuat dengan nilai antara 62%-92% perencatan. Keputusan ini menunjukkan bahawa integrasi cuka kayu dengan sungkupan mengikut kadar tertentu menyediakan kawalan optimum untuk *H. verticillata*, sekaligus menonjolkan potensi yang cerah sebagai kaedah kawalan rumpai berhubung dengan pengurusan rumpai yang jitu.

Kata kunci: *Hedyotis verticillata*, cuka kayu, sungkupan sabut kelapa, perencatan.

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LIST OF SYMBOLS

g	-	Gram
mg	-	Milligram
µg	-	Microgram
w/v	-	Weight per volume
%	-	Percent
g/L	-	Gram per litre
g ML^{-1}	-	Gram per millilitre
t ha^{-1}	-	Tan per hectare
ml	-	Millilitre
L/ha	-	Litre per hectare

LIST OF ABBREVIATIONS

ANOVA	-	Analysis of Variance
SPSS	-	Statistical Product and Service Solution
HSD	-	Honest Significance Different
Sig	-	Significant
SD	-	Standard Deviation

CHAPTER 1

INTRODUCTION

1.1 Background of Research

Weeds are similar to plants. It's a living thing that reacts to its surroundings. The weed plant can thrive and grow in an environment and conditions that are conducive to its development. Weeds are plants that are avoided by consumers, are not applied to plants, and are undesirable under human control conditions, especially in agriculture and gardens. Yards, parks, woodland, and other areas are popular breeding places for these weeds. These species are plants that grow and reproduce vigorously and are potentially invasive species (Harlan and deWet, 1965). Owing to its adverse effects on agricultural farms, this crop species is commonly regarded as a weed in agronomic cultivation systems (Gaddeya & Ratnakumar, 2014). Weeds in crop fields compete with crop plants for light, moisture, and other essential nutrients, resulting in lower crop yield and quantity. As a result, weeding utilizes a major portion of the cost budget in order to minimise weed competition on this crop (Lim, 1997).

Woody borreria is a perennial crop and spreading herb as scientific name of *Hedyotis verticillata* (L.) Lam. It also belongs to the *Rubiaceae* family. In 2005, this weed was discovered spreading in the palm oil region of Malaysia (Chuah, 2014). This crop is a broad-leaved weed widely found in farm areas such as oil palm and rubber plantations. It can also reach a height of 15-100 cm with a smooth or hispid taproot and a robust taproot. The flowers are rarely independent, and the sepal tube is hairless or pubescent. The name woody borreria is taken in conjunction with when this *H. verticillata* weed is mature, the stem will turn woody core and hard to manage (Chuah et al. 2005). As a result, this weed is one of the more difficult to eradicate and control weeds due to its short, fast, and easy breeding period. Farmers are affected because they need the appropriate tools and methods to monitor and handle the weed issue.

According to Chuah and Ismail (2010), *H. verticillata* is a weed that has been used as an herbicide that is resistant to several types of herbicides on the market such as paraquat, glyphosate, and metsulfuron. The susceptible biotype will die by the time the herbicide is applied to the crop area. Those resistant to herbicides and resistant biotypes, on the other hand, can survive, develop, and produce seeds. When herbicides of the same type are used repeatedly, resistant weed populations will emerge.

Mulching is indeed beneficial in controlling and growing the number of weeds that emerge. Mulching is any substance that is scattered or laid as a covering over the soil's surface. Mulch has many advantages, including the ability to preserve soil moisture, improve soil fertility and health, minimize weed growth, and improve the aesthetic appeal of the area (Vanderlinden, 2017). Coco peat, chipped bark, chopped leaves, straw, and compost are also several types of mulching options available for use in the garden and on

crops. Coco peat mulching is a natural by-product derived from the processing of fibres from the coconut husk from the inside of the coconut shell. It is indeed tightly packed, which allows it can expand when added to moisture.

Furthermore, wood vinegar is a liquid material made by pyrolyzing biomass in a specific and regulated manner. Wood vinegar is thought to contain over 300 components, including acetic acid, methanol, phenol, ester, acetals, ketone, formic acid, and others (Michael, 2011). It has bactericidal properties as well as the potential to spread microbes. It has a growth-inducing effect due to its radicational properties. However, depending on the consistency of the mixture, it may also be used to slow down the plant's development. It was claimed to be efficient against wheat rosette or green mosaic, butternut squash nematode, tobacco mosaic, powdery mildew in leafy greens, leaf miner, and other insect pests in the early 1950s. Unfortunately, due to the advent of agrochemicals and their immediate results, wood vinegar research was halted. As the efficacy and protection of agrochemicals are called into question, interest in wood vinegar resurfaced in the early 20s.

1.2 Problem Statement

Cultural, physical, chemical, and biological weed control are the most common weed control methods used by farmers. Chemical herbicide applications, on the other hand, are one of the most efficient techniques of weed control. However, this application is becoming even more costly in recent years, and it also leads to emissions. The use of chemical herbicides on a regular basis will cause weed populations to develop vulnerability or resistance to the herbicide (Gaddeya and Kumar, 2014). Each weed-control strategy has its own collection of advantages and disadvantages. To resolve these issues, a new weed control strategy is needed.

Chemical herbicide application is one of the most efficient methods for controlling weed growth. Continuous uses of chemical herbicides, on the other hand, tend to make plant species resistant to the herbicide. Herbicide costs will increase as a result of the weeds' resistance, and there will be a large build-up of herbicide in the soil. Furthermore, though herbicides are aimed at destroying plants, it can be harmful to human safety.

Application of coco peat mulching on the crop field for example, offers various benefits such as conserving soil moisture, increasing organic matter content, preserving soil fertility, and retarding weed development without using chemicals (Dilipkumar et al. 2017). Mulching also suppresses weeds due to the action of phytotoxic compounds in the mulch (Verdu and Mas, 2007). The key advantage of mulch application, according to Jodaugiene et al. (2012), is nutrient contribution. The time needed for the mulching to

release nutrients, on the other hand, is relatively long and sluggish. As a result, using wood vinegar extract in combination with mulching would enhance the inhibition activity on weeds, as wood vinegar contains over 200 chemicals, including acetic acid, formaldehyde, ethyl-valerate, methanol, tar, and others, which can kill weeds more efficiently (Halde and Martin. 2015). Wood vinegar is widely used by farmers and consumers for pest control and plant growth, but no research has been done on its use for weed control.

1.3 Hypothesis

HO: There were no significant inhibition on the emergence and growth of woody borreria (*Hedyotis verticillata* (L.) Lam.) after application of coco peat mulch treated with wood vinegar.

H1: There a significant inhibition on the emergence and growth of woody borreria (*Hedyotis verticillata* (L.) Lam.) after application of coco peat mulch treated with wood vinegar.

1.4 Objectives

The objective of this study is to:

1. Determine the effect of different application rates of coco peat mulch treated with wood vinegar on the emergence and growth performance of woody borreria weed (*Hedyotis verticillata* (L.) Lam.).

1.5 Scope of the study

This study was focus on the efficacy of coco peat mulch treated with wood vinegar on the emergence, root length and shoot fresh weight of woody borreria (*Hedyotis verticillata* (L.) Lam.) at the vegetative stage. The tested weed were treated with different rates of coco peat mulch and wood vinegar in order to find the most efficient combination rate to control woody borreria.

1.6 Significant of the study

To increase the competitiveness with weeds and achieve the optimum of crop growth, weed management needs a new strategy towards achieving sustainable best agricultural practices. One of the alternatives are through integration of mulching and wood vinegar application. A combination of organic mulching (cultural method) and wood vinegar (natural pesticide) was proposed in this study in order to reduce the dependence of the chemical herbicide in the crop field. As a result, this study helpful in introduced the new approach of weed control strategy.

CHAPTER 2

LITERATURE REVIEW

2.1 Wood Vinegar

2.1.1 Origin and Distribution of Wood Vinegar

A thick, brownish liquid identified as wood vinegar or *Pyroligneous* acid or wood acid. It is made by burning wood without oxygen to create charcoal. There will be white smoke, sharp smoke, and smoke of perfection after the wood has gone through a pyrolysis process. Wood vinegar is produced once it is cold. Wood vinegar's efficacy as a foliar or contact herbicide was reported by Kim et al. (2000). The study found that foliar application of wood vinegar had herbicidal activity against *Echinichloa crus-galli* at various growth stages, but no inhibition effect was found when the wood vinegar was applied to the soil. Other research has shown that vinegar can be used as a low-cost herbicide in organic cultivation as a spot treatment (Radhakrishnan et al., 2002). Despite wood vinegar's high dissolved organic carbon content, its high fertilising effect, which promoted robust growth and root activity in seedling growth, it is indeed possible that it increases herbicide uptake and translocation in plants, thereby increasing efficacy and

phytotoxicity. Since it contains a high amount of organic compounds, wood vinegar can influence the value and activity of chemical herbicides in soil systems. However, if the dissolve organic matter converted on the soil particle produced additional pesticide solubility sites, it might improve herbicide solubilisation (Gigliotti et al., 2005).

Wood vinegar can be processed in three different ways such as thermal, chemical, and biochemical (Kim et al., 2000). Land resources like wood bark and waste from the forestry industry and agricultural resources are also possible natural resources for the production of vinegar like bamboo, husk and rice straw, sugarcane and sugarcane waste, corn stalks, cotton stalks. The quality of the wood vinegar produced varies as well in terms of chemical composition and properties. Wood vinegar derived from woody plant sources has been shown to improve seed germination of seeds development.

2.1.2 Application of Wood Vinegar in Agriculture

There are numerous advantages to using wood vinegar. They will all help to speed up seed germination. According to studies, the development of wood chaff from bamboo burning accelerates plant growth (Kim et al. 2000). As a result, farmers with difficult-to-germinate plants would usually spray wood vinegar on their crop seedlings. According to a report, wood vinegar derived from woody plant sources such as oak, rubber wood, walnut, or mangrove wood is the best option for ensuring that the tree grows well. Because of the ester presence in this wood vinegar, it will help this plant grow and mature faster. When a tree is treated with wood vinegar, the tree grows twice as quickly and more fertile. Furthermore, since it contains a high amount of antioxidants and phonetics, wood

vinegar is an organic pesticide that is safe for crops. This wood vinegar works by generating microbes, which are organisms that consume pests that attack our crops. It is also safe to use because it contains secure and organic material. Furthermore, wood vinegar is commonly used as a weed killer. This is due to the high organic content of wood vinegar.

2.1.3 Chemical Properties in Wood Vinegar

Wood vinegar is a complex combination containing a large number of carbon and oxygen molecules. Wood vinegar is a complex mixture of compounds with differing molecular structures that results from the gradual and overlapping degradation and depolymerisation of three polymers found in plant biomass: cellulose, hemicellulose, and lignin (Zhang, Q et al. 2007). Wood vinegar's nature and chemical composition are affected by current density, temperature range, heat, chemical composition, and raw material source (Mohan, D., et al. 2006). Water, acetic acids, catechol, furancarboxaldehydes, isoeugenol, formic acid, syringols, vanillins, pyrones, guaiacols, as well as other chemical groups also including hydroxyaldehyde, hydroxyacetaldehyde, glucose, formapheniloc, hydroxyketone and carboxylic acid, alkane, ethanol, and ester help compensate biomass-based (Mohan, D., et al. 2006). Apart from that, the main compound, acetic acid, comprises approximately 50% of the total, giving it its characteristic low pH of 3, and the phenolic group gives it its distinctive smoky aroma.

2.1.4 Other Plant Extraction

Table 2.1.4: The types of plant extract or natural product and its effect on the bioassays species

Types Of Plant Extract	Active Concentration	Bioassay Species	Percentage Of Inhibition	References
Sunflower leaf extract	10 -15% (w/v)	Barnyard grass *(Echinochloa crus-galli)* Barnyard grass (*Echinochloa crus-galli)*	Inhibit the weeds emergence by 80-90%	Dilipkumar and Chuah, (2013)
Chitosan	10% and 5% (g mL^{-1})	Wild poinsettia (*Euphorbia heterophylla*) Morning glory (*Ipomoea grandifolia*)	Inhibit the development of the root part more than 60-80% for all species in both concentration	Novaes et al. (2013)
Natural Plant Oil	4,8,12,16 and 20g per 100 ml of water	Quack grass (*Agropyrum repens)*	Inhibit the radical at the lowest compared to other parts of tissue extract	Ashafi et al. (2009)
Aqueous curry *(Murraya koenigii)* leaves extract	10%	Basmati (cv. Kasturi) Non- Basmati (cv. Plant dhan11)	Reduced the shoot fresh weight by 17.5 mg	Indracanti & Dadh, (2015)

2.2 Weed management

2.2.1 The application of mulching

Mulching is any substance that is scattered or laid as a coating over the soil's surface. As this mulch forms a protective layer between the sun and the soil, it is used to fight weed species. As a result, weeds have a hard time establishing itself. Mulch also assists in the enhancement of soil fertility. This is because organic mulches decompose over time and provide nutrients to the soil. Shredded hardwood mulch, cypress mulch, fresh wood chips, and compost materials are types of mulch that can be used in the field (Venderlinden, 2018).

2.2.2 Effect of mulching on the weed growth

Mulch can be used to improve crops, beds, and gardens in a variety of ways. Mulches like coco peat can help to reduce weed growth by making conditions undesirable for weed seed germination and providing a physical barrier for emerging weeds. A well-applied mulch layer will save a lot of time when it comes to weeding. In the garden and bed, a thick layer of mulches components is particularly effective at reducing the number of annual weeds. This is due to the fact that weeds have a hard time breaching the dense layer of mulch (Relf, 2015).

There are several different methods of mulching that have been used as weed suppressants in previous studies. As a result, the effect of various forms of mulching alone and mulching treated with herbicide on the target weed variety differs.

2.2.3 The Type of Mulches

Wood Chips Mulch

Wood chips are a form of mulch manufactured in a variety of hardwood and softwood products. It can often be accessible from municipalities or tree-pruning as well as clearing trees. Typically, wood chip mulch has a high carbon nitrogen ratio. It suggests that the decomposition of this mulch will temporarily reduce the amount of nitrogenous fertilizers supplied to mulched plants (Rakov, 1998). The potential of wood chips mulch from a few varieties of woody perennials, such as Southern Redcedar and Southern Magnolia, to suppress weeds is attributed to the reason that it contains a water-soluble natural product with phytotoxic activity that could be used to eliminate the plant. However, this type of mulch has its own set of drawbacks. For example, a fungus called shotgun infection caused by rotting wood may cause a farmer several plethora of troubles. As a result, it is suggested that it would not use the wood chips alone, but rather cover them with a layer of another kind of mulch as an alternative technique (Rakov, 1998).

Sawdust Mulch

Sawdust mulch is a form of mulch commonly recommended for blueberry and other acid-loving evergreen crops. This is due to the fact that when the mulch decomposes, it has the potential to acidify the soil. Furthermore, sawdust mulch is similar to wood chips mulch in that both mulches have the potential to deplete nitrogen in the soil (Rakov, 1998). This type of mulch, according to Ferguson et al. (2008), not only reduced weed emergence in nursery plants, but it also reduced nitrogen accessibility due to high carbon nitrogen ratios.

Shredded or Chipped Bark Mulch

This type of mulch is normally difficult to decompose and does not provide a lot of nutrients to the soil (Venderlinden, 2018). Furthermore, the herbicide-treated chipped bark was able to increase the pre-emergent herbicide's weed control effectiveness by nearly 15% thus lowering nursery plant phytotoxicity. Due to the high carbon-nitrogen ratios, this type of mulch not only reduced weed emergence when planted in a nursery pot, but it also decreased nitrogen efficiency.

Straw Mulch

Straw mulch, which can be formed from wheat, rye, oat, or barley, is a type of mulch. This type of mulch is commonly used in vegetable gardens and strawberry plantings as winter mulch around tree or shrub roots and summer mulch in vegetable gardens and strawberry plantings. However, since it is largely made up of carbon, this form of mulch has a limitation. The growth of the plant necessitated a sufficient amount of nitrogen, and the breakdown of the high-carbon plant also requires nitrogen. The plant would be deprived of nutrients rather than being fertilised by the straw mulch if the soil contains the least amount of nitrogen. To prevent being deprived of nitrogen, it is recommended that compost was added to the crop field before the straw mulch is applied (Baley, 2018). This form of mulch, on the other hand, is inexpensive and effectively inhibits weeds while also reducing soil water losses. Furthermore, as a winter mulch, it protects tender rots from damage caused by cold temperatures (Rakov, 1998).

Black Plastic Film Mulch

A type of synthetic mulch widely used in the crop field is black plastic film mulch. It is made up of petroleum, which is a non-renewable resource (Schonbeck, 2012). It is

always commonly used in vegetable and small fruit plantings, and it is also often used as a layer under wood, bark, or mineral chips (Rakov, 1998). The aim of black plastic film mulch is to keep the soil moist while suppressing the number of weeds. As a result, weed control can help manpower and expenses will be minimised. However, in contrast to other organic mulches, this mulch will not provide any organic matter to the soil due to its synthetic properties.

Clear, Translucent, and Coloured Plastic Films

Finally, there were also clear and translucent films available on the market. However, as opposed to black plastic mulch, this type of mulch only warms the soil to a greater extent but does not effectively kill weeds (Schonbeck, 2012). Furthermore, the invention of coloured plastic mulches, such as translucent green, brown, olive, and IRT (infrared-transmitting) plastic films, has improved soil warming. While this type of mulch absorbs the red and blue light wavelengths that plants use in photosynthesis whereas transmitting more infrared (heat) wavelengths and some green light, weed germination, emergence, and development will be reduced as compared to clear film or bare soil (Schonbeck, 2012).

2.2.4 Application of Other Types of Mulching and Herbicide

Table 2.2.4: The application of other types of mulching and herbicide and its effect on the bioassays species.

Types of Mulching	Active Concentration	Bioassay species	Effect	References
Oil palm mulches (frond, leaflet and rachis)	3 tan / ha $^{-1}$	Goosegrass (*Eleusine indica)*	85-100% inhibition	Dilipkumar et al. (2015)
Rice (husk) residues	3 tan / ha $^{-1}$	Goosegrass (*Eleusine indica)*	70-80% inhibition	Dilipkumar et al. (2015)
Oil palm residue (frond, leaflet and rachis) + Imazethapyr	1.4 - 1.8 tan / ha $^{-1}$ + 12 g ai ha $^{-1}$	Goosegrass (*Eleusine indica)*	90-100% inhibition	Dilipkumar et al. (2017)
Wheat straw shredded	5.08 cm thick	Zinnia *(Zinnia elegans)*	Had the lowest mean of weed cover	Mutalleb, (2018)
Santa-Maria(*Parthenium hysterophorus)* mulch	5 tan / ha $^{-1}$	Soybean (*Glycine max)*	Gave strong reduction on shoot fresh weight	Siddiqui et al. (2018)

2.3 Woody Borreria (*Hedyotis verticillata* (L.) Lam.)

2.3.1 Origin and Distribution of Woody Borreria

Figure 2: Woody Borreria (*Hedyotis verticillata* (L.) Lam.)

Hedyotis verticillata Lam., also known as woody borreria or harsh-leaved *Hedyotis*, is a *Rubiaceae* family creeping perennial (Barnes and Chan 1990). It is indeed a broadleaved weed that has become one of the most troublesome perennial weeds in Malaysian oil palm cultivation in recent years. When woody borreria stems become lignified, controlling them becomes more challenging (Ong and Teo 1990). The weed was assigned the name woody borreria for its similarity to *Borreria laevicaulis (Ridley*) (Yap and Ng, 1986). The term "woody" refers to mature plants with woody stems. Woody borreria is a tropical American plant that can be found in the wild on Java Island (Backer

and Bakhuizen van den Brink, 1965). According to Yap and Ng (1986) woody Borreria as a noxious weed in Malaysian oil palm and rubber plantations. In Johor, woody borreria was identified in 22% of the estate studied.

2.3.2 Taxonomic status

Woody Borreria can rises to a height of 1.5 meters. It also reproduces by seeds. Indeed, the leaves of the woody borreria have a unique fragrance. When the seeds germinate very closely to one another in natural conditions, and as a result of rivalry, it appears small with few branches. Beside that it will produces various branches in open and spacious conditions. The stems are wiry and woody. Leaves of these species are Oblong-Lanceolate, with 5-8 pairs of nerves, scabrous by small bristles near margin only, sometimes finely puberulous or glabrous. The stems of this weed are obtusely quadrangular, angles with retrorse, fine, usually short hairs. The seeds to be horizontally stripes and narrow (Backer and Bakhuizen van den Brink, 1965)

Kingdom	: Plantae
Sub Kingdom	: Angiosperms
Order	: Gentianales
Family	: Rubiaceae
Subfamily	: Rubioideae
Genus	: *Hedyotis*
Species	: *H. vertilillata*

Figure 2.3.2: Taxonomy of Woody Borreria (Ong and Teo, 1990)

2.3.3 Morphological characteristic

Woody borreria appeared 7 days after the sowing process, according to studies on phenological and reproductive characteristics. On the 51st day after sowing, it formed flowers. Fruit matures and produces 7 to 14 days after flowering, and capsules mature and discharge 14 to 21 days after fruiting. Plants grown in the open and under light with a 36 percent reduction in light transmission rate will produce 15,000 seeds per plant, while plants with a 9 percent light transmission rate will develop 6,500 seeds per plant, and plants with a 1 percent light transmission rate will develop 10 seeds per plant.

CHAPTER 3

MATERIALS AND METHOD

3.1 Materials

3.1.1 Mulching

Coco peat were bought from the Secret Garden Nursery, Tanah Merah, Kelantan in September 2021.

3.1.2 Plant Material

The seeds of *Hedyotis verticillata* (L) Lam. were collected from Agro Techno Park in University Malaysia Kelantan Jeli Campus September 2021.

3.1.3 Wood Vinegar

Wood vinegar were bought from the Secret Garden Nursery, Tanah Merah, Kelantan in September 2021.

3.1.4 Apparatus and Equipment

In this study, there are several apparatus and equipment's that are going to be used as in the Table 3.1.4 below:

ACTIVITY	APPARATUS / EQUIPMENTS
1. Treatment preparation	- Micropipette - Beaker - Petri dish - Cotton pad
2. Seedling growth test	- Seedling tray - Paper cup - Watering can - Gloves - Scoop - Pressure sprayer
3. Data collection	- Digital scale (shoot fresh weight) - Measuring tape (root length)
4. Data analysis	- SPSS SOFTWARE

3.2 Methods

3.2.1 Seedling growth test

The experiment was done in nursery of University Malaysia Kelantan, Jeli Campus with humidity rate at 78-80% and temperature ranging from 28-30°C. The seeds of *H. verticillata* will be scarified with sandpapers in order to slightly break the outer coat to allow water to penetrate the seeds (Hodgson, 2016). A paper cup were filled with 115 g of topsoil and placed in a 40 x 30 x 5 cm tray. For growth test, 20 *H. verticillata* seeds were sowed for each paper cup with the holes at the bottom. The water were applied from the bottom of the paper cup to stimulate moist condition for proper growth of *H. verticillata* seedling under nursery conditions (Dilipkumar et al.2017). One day after sowing, the coco peat mulch treated with wood vinegar will be applied onto the soil surface as follows:

Table 3.2.1: No of treatments and application rate of coco peat mulch (t ha^{-1}) + wood vinegar concentration (%)

Treatment	Application Rate of Coco Peat Mulch (t ha^{-1}) + Wood Vinegar Concentration (%)
Control T0 (A)	4 t ha^{-1} coco peat mulch + 0% wood vinegar
Control T0 (B)	8 t ha^{-1} coco peat mulch + 0% wood vinegar
Control T0 (C)	12 t ha^{-1} coco peat mulch + 0% wood vinegar
Treatment 1 (T1)	4 t ha^{-1} coco peat mulch + 10% wood vinegar

Treatment 2 (T2)	4 t ha^{-1} coco peat mulch + 20% wood vinegar
Treatment 3 (T3)	4 t ha^{-1} coco peat mulch + 30% wood vinegar
Treatment 4 (T4)	8 t ha^{-1} coco peat mulch + 10% wood vinegar
Treatment 5 (T5)	8 t ha^{-1} coco peat mulch + 20% wood vinegar
Treatment 6 (T6)	8 t ha^{-1} coco peat mulch + 30% wood vinegar
Treatment 7 (T7)	12 t ha^{-1} coco peat mulch + 10% wood vinegar
Treatment 8 (T8)	12 t ha^{-1} coco peat mulch + 20% wood vinegar
Treatment 9 (T9)	12 t ha^{-1} coco peat mulch + 30% wood vinegar

The spraying volume for wood vinegar was 450 L/ha (Mohammad, Ghahraei, Ahmad, Reza & Mohammad, 2014). Hence, based on the spraying volume, 0.088ml of wood vinegar solution were applied on the soil surface of each tested seedling according to its respected concentration by using micropipette. The distilled water were applied as a control. The cup then were placing under nursery and humidity that with 78-80% and also the temperature between 28-30℃. The data were collected 14 days after the treatment's application. The number of emerged weed seedlings, the root length and the shoot fresh weight were measured, and data were expressed as percentage of control (% of control).

3.3 Statistical Analysis

All the treatments were arranged in completely randomized design (CRD) with three replications. All data were subjected to one-way ANOVA analysis. The Turkey test HSD was used to compare the mean among the treatments. Differences were regarded as significant the p-values were less than 0.05 ($p<0.05$).

3.4 Research flow chart

Preparation of Planting Media

20 seeds of *H. verticillata* were sowed for each small-sized paper cup that formerly filled with 115g of top soil as growing medium

Treatment Preparation

The treatments were applied to the soil one day after sowed the seeds as follow;

- **T0 (A)** (4 t ha^{-1} coco peat mulch + 0% wood vinegar concentration)
- **T0 (B)** (8 t ha^{-1} coco peat mulch + 0% wood vinegar concentration)
- **T0 (C)** (12 t ha^{-1} coco peat mulch + 0% wood vinegar concentration)
- **T1** (4 t ha^{-1} coco peat mulch + 10% wood vinegar concentration)
- **T2** (4 t ha^{-1} coco peat mulch + 20% wood vinegar concentration)
- **T3** (4 t ha^{-1} coco peat mulch + 30% wood vinegar concentration)
- **T4** (8 t ha^{-1} coco peat mulch + 10% wood vinegar concentration)
- **T5** (8 t ha^{-1} coco peat mulch + 20% wood vinegar concentration)
- **T6** (8 t ha^{-1} coco peat mulch + 30% wood vinegar concentration)
- **T7** (12 t ha^{-1} coco peat mulch + 10% wood vinegar concentration)
- **T8** (12 t ha^{-1} coco peat mulch + 20% wood vinegar concentration)
- **T9** (12 t ha^{-1} coco peat mulch + 30% wood vinegar concentration)

Treatment application: 0.088 ml of wood vinegar (spraying volume of 450 L/ha)

Data Collection

All the parameters were measured after 14 days of treatment application. The number of emerged weeds, the shoot fresh weight and the root length were measured.

Analysis Data

All the measurement were done in three replicates. Then, the data were subjected to using One-Way ANOVA (SPSS Version 21).

Figure 3.4: Research flow chart

CHAPTER 4

RESULT AND DISCUSSION

4.1 Effect of coco peat mulch treated with wood vinegar on control (*Hedyotis verticillata* (L.) Lam.) at the vegetative stage under nursery conditions.

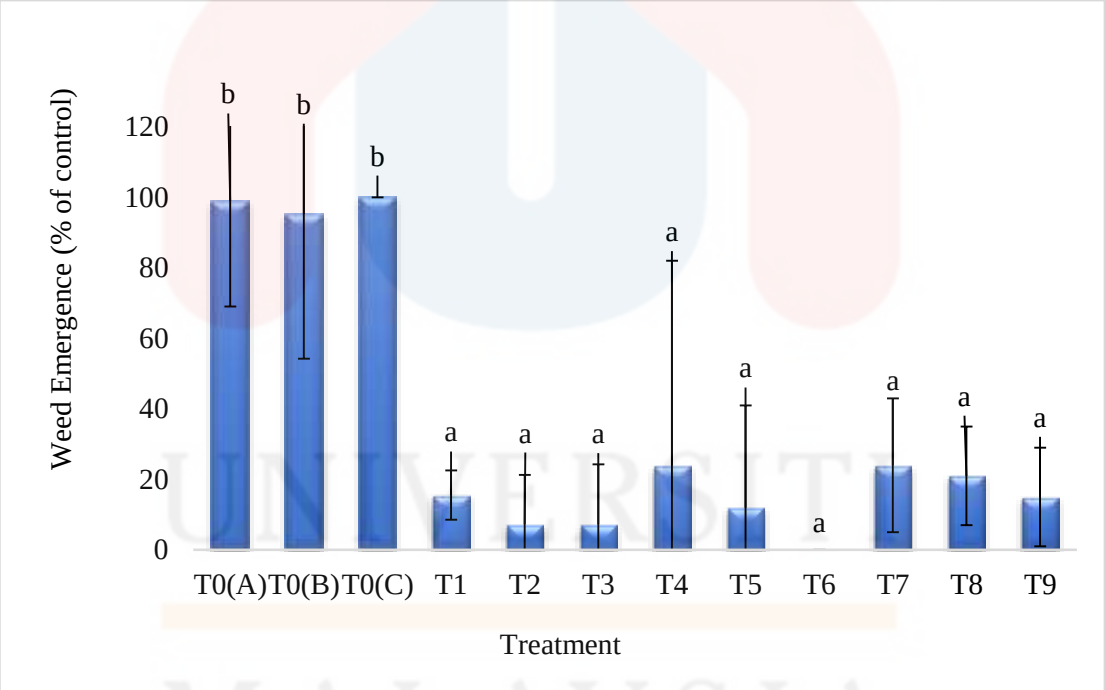
4.1.1 Weed Emergence

The effect of coco peat mulch treated with wood vinegar on the weed emergence of *H. verticillata* was shown in Figure 4.1. Regardless of any application rate of coco peat mulch and wood vinegar, the mean value (% of control) of weed emergence of the bioassay species was significantly reduced (Appendix B). It was interesting to note that *H. verticillata* that treated with 8 t ha^{-1} coco peat mulch + 30% wood vinegar (**T6**) was completely inhibited by 100%. Even though the application rate of coco peat mulch (4 t ha^{-1} – 12 t ha^{-1}) and wood vinegar (10% - 30%) starting from **T1** to **T9** showed no significant difference with **T6,** these treatments application still exhibit strong inhibition on the weed emergence with the inhibition value ranging from 76 – 93%.

There are limited findings from previous study regarding the effect of mulching treated with plant extract or natural compound for weed control. However, many studies have been conducted to determine the phytotoxic activity of herbicide in combination with crop residue or organic mulch on weed. These previous researches showed various results, from no interaction (Chauhan & Abugho 2013; Mathers & Case 2010), antagonism (Chauhan & Abugho 2012; Teasdale et al. 2013) or synergism (Mathew & Case 2010; Teasdale et al. 2005) depending on the type and rate of herbicides and crop residues used. For instance, Dilipkumar et al. (2017) demonstrated that the application of oil palm frond, leaflet, and rachis at lower application rate of 1.4-1.8 t ha^{-1} treated with 12g ai ha^{-1} of imazethapyr gave significant inhibition on the emergence of goosegrass (*Eleusine indica*) by 90-100% inhibition under glasshouse condition. Furthermore, they also found that oil palm residues at higher rate of 3.4 t ha^{-1} treated with 24 g ai ha^{-1} imazethapyr inhibit 90% the weed emergence of Panicgrass (*Panicum sp*), Bhui-amla (*Phyllanthus amarus*), and Chinese violet (*Asystasia gangetica*) under field conditions. In another study, Mathers and Case (2010) compared microencapsulated (ME) and emulsifiable concentrate (EC) formulations of acetochlor and alachlor with or without pine nuggets, Douglas fir bark, and hardwood mulches. They observed that Douglas fir bark is not effective as a mulch to be treated with either of those herbicides. Only one combination of herbicide and mulch, acetochlor EC treated Douglas fir bark, resulted in a weed control rating >7.

These previous results suggest that different thickness of mulching will provide different level of weed control; and when herbicides were combined with mulching, they provided excellent weed control even at lower thicknesses. In contrast, the present showed

that the application of different thickness (in kg ha^{-1}) of coco peat mulch and different concentration of wood vinegar provide sufficient weed control where the emergence of *H. verticillata* was strongly inhibited ($p<0.05$) (Figure 4.1). These current results indicate that the proper combination of wood vinegar and coco peat, and wood vinegar placement relative to the mulch can provide acceptable weed control. Besides, it is clearly shown that the mean values for emergence of *H. verticillata* in all treatments (**T1-T9**) (Figure 4.1) are strongly inhibited where the weed emergence inhibition achieve >50% after subjected to coco peat mulch and wood vinegar application. These results implied that both wood vinegar and the coco peat mulch are strong weed inhibitors.



TO(A) : 4 t ha^{-1} coco peat mulch + 0% wood vinegar

TO(B) : 8 t ha^{-1} coco peat mulch + 0% wood vinegar

TO(C) : 12 t ha^{-1} coco peat mulch + 0% wood vinegar

T1 **:** 4 t ha^{-1} coco peat mulch + 10% wood vinegar

T2 **:** 4 t ha^{-1} coco peat mulch + 20% wood vinegar

T3 **:** 4 t ha^{-1} coco peat mulch + 30% wood vinegar

T4 **:** 8 t ha^{-1} coco peat mulch + 10% wood vinegar

T5 **:** 8 t ha^{-1} coco peat mulch + 20% wood vinegar

T6 **:** 8 t ha^{-1} coco peat mulch + 30% wood vinegar

T7 **:** 12 t ha^{-1} coco peat mulch + 10% wood vinegar

T8 **:** 12 t ha^{-1} coco peat mulch + 20% wood vinegar

T9 **:** 12 t ha^{-1} coco peat mulch + 30% wood vinegar

Figure 4.1: The effect of coco peat mulch treated with wood vinegar on weed emergence of *Hedyotis verticillata*. Vertical bar represent standard deviation (SD) of the mean.

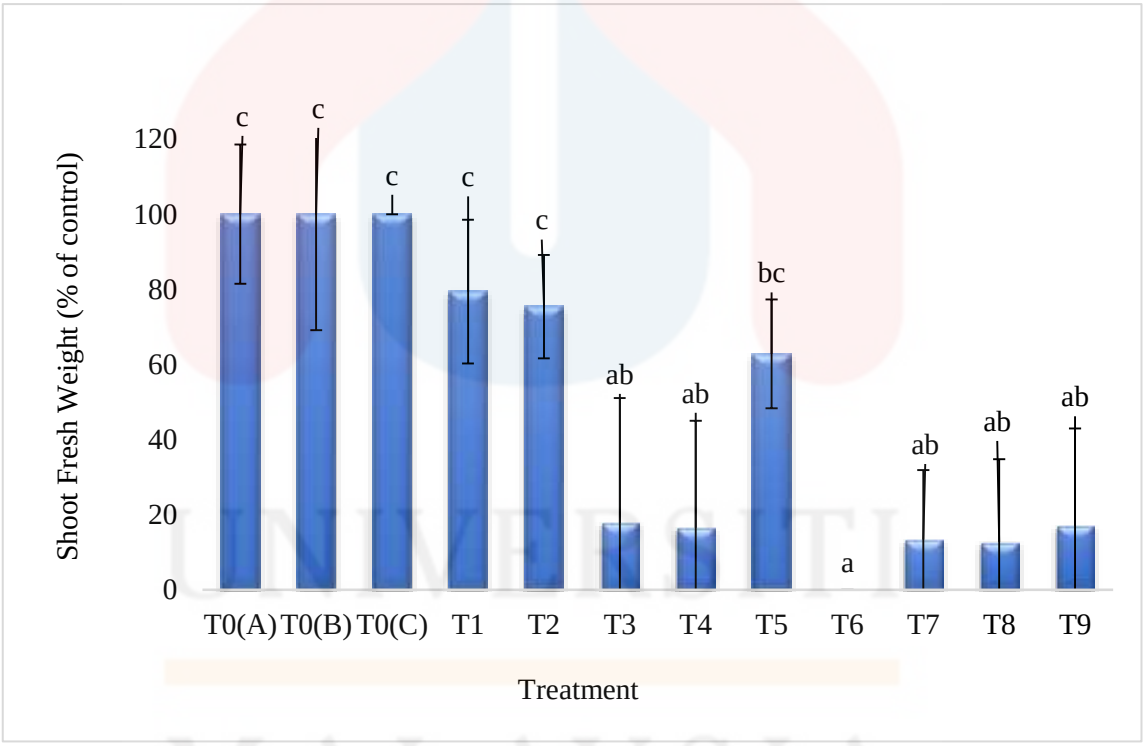
4.1.2 Shoot Fresh Weight

The effect of coco peat mulch treated with wood vinegar on the shoot fresh weight of *H. verticillata* was shown in Figure 4.2. It was found that there was significant reduction on the shoot fresh weight of *H. verticillata* starting from 4 t ha^{-1} - 12 t ha^{-1} coco peat mulch with the wood vinegar concentration ranging from 10% - 30% (**T3, T4, T6, T7, T8,** and **T9**). At these application rates, the shoot fresh weight of the bioassay species was strongly inhibited by 82-100% ($p<0.05$). Similar to the weed emergence, **T6** shows strong reduction on shoot fresh weight where it reduced by 100% (Appendix B). Furthermore, it was found that **T1**, **T2** and **T5** exhibit less percentage on shoot fresh weight with 21%, 25% and 37% inhibition, respectively (equal to 79, 75 and 63, % of control; respectively).

The effect of mulching that being treated with herbicide or other natural compound on the shoot fresh weight of weeds have been reported in many studies. According to a study conducted by Derr (1994), the excellent control on weed shoot fresh weight (50% inhibition) was observed in the treatment with combination of pine nuggets in a single layer plus oxyfluorfen and pendimethalin at 2.0 g and 1.12 kg/ha, respectively. Furthermore, Wells et al. (1987) reported that there is a 3-fold increase in shoot fresh weight reduction of weed after using pine bark mulches treated with herbicides rather than pine bark alone. Chauhan and Abugho (2013) reported that application of oxadiazon at 0.5 kg a.i. ha^{-1}, followed by fenoxaprop plus ethoxysulfuron at 0.45 kg a.i. ha^{-1} treated rice straw mulch at 2 or 4 t ha^{-1} reduced total weed biomass by 93-98% as compared with untreated plots.

From these finding, it appears that in addition to providing a physical barrier to weeds, mulches treated with herbicide resulted in the highest weed control. It is possible

that the herbicide increases the mulching efficacy in prevented germination and/or establishment of weeds by induce the release of allelopathy compound from the mulch. Similar to this current study, the reduction of *H. verticillata* fresh weight by the coco peat mulch is rate-dependent (Figure 4.2), suggesting that the reduction is most likely due to physical barrier or/and allelopathy effect of the residue mulches triggered by different concentration of wood vinegar to provide unfavourable condition for the weed growth. This physical barrier helps in reducing light penetration and decreased soil temperature fluctuation, thereby resulting in inhibition of weed germination and growth (Kruidhoff et al. 2009; Liebman & Mohler 2001).



TO(A) : 4 t ha^{-1} coco peat mulch + 0% wood vinegar

TO(B) : 8 t ha^{-1} coco peat mulch + 0% wood vinegar

TO(C) : 12 t ha^{-1} coco peat mulch + 0% wood vinegar

T1 : 4 t ha^{-1} coco peat mulch + 10% wood vinegar

T2 : 4 t ha^{-1} coco peat mulch + 20% wood vinegar

T3 : 4 t ha^{-1} coco peat mulch + 30% wood vinegar

T4 : 8 t ha^{-1} coco peat mulch + 10% wood vinegar

T5 : 8 t ha^{-1} coco peat mulch + 20% wood vinegar

T6 : 8 t ha^{-1} coco peat mulch + 30% wood vinegar

T7 : 12 t ha^{-1} coco peat mulch + 10% wood vinegar

T8 : 12 t ha^{-1} coco peat mulch + 20% wood vinegar

T9 : 12 t ha^{-1} coco peat mulch + 30% wood vinegar

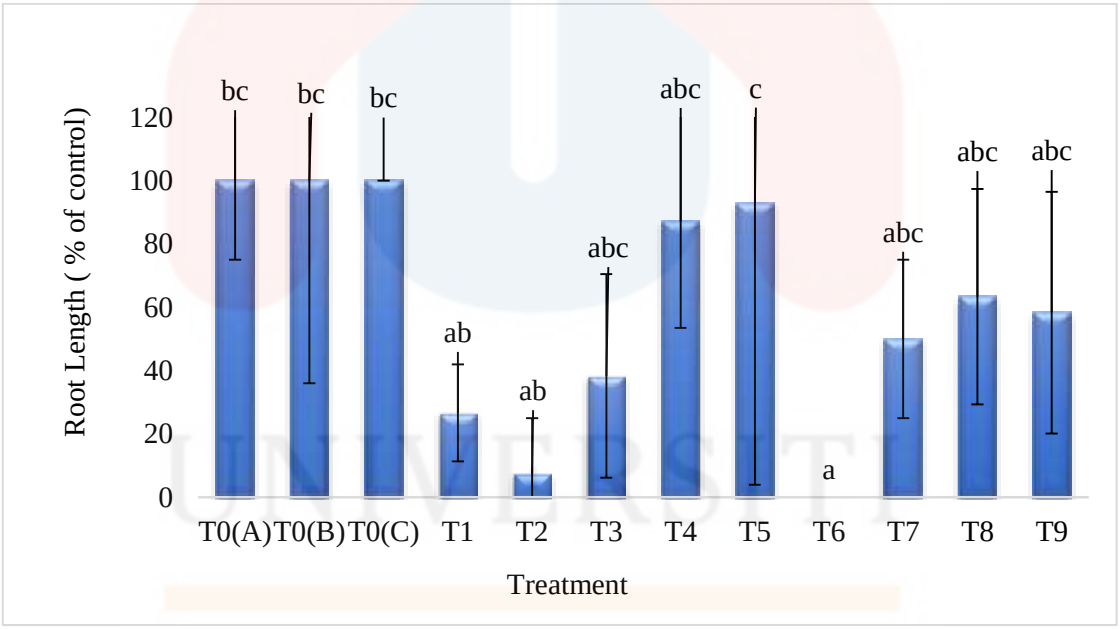
Figure 4.2: The effect of coco peat mulch treated with wood vinegar on shoot fresh weight of *Hedyotis verticillata*. Vertical bar represent standard deviation (SD) of the mean.

4.1.3 Root length

Figure 4.3 shows the effect of coco peat mulch treated with wood vinegar on the root length of *H. verticillata.* Similar to the weed emergence and shoot fresh weight, the root length was significantly reduced at **T6** (8 t ha^{-1} coco peat mulch + 30% wood vinegar) by 100% as compared to the control. However, at the same thickness of coco peat mulch (8 t ha^{-1}), **T4** and **T5** showed less root inhibition with 7% and 13% inhibition, respectively. Even though no significance difference were detected at the lower application of coco peat mulch at 4 t ha^{-1} (**T1**, **T2** and **T3)** as compared to the control, these application rates show strong root reduction with the value ranging from 62%-92% inhibition (Appendix B). Furthermore, it was noted that at an application rate of 12 t ha^{-1} coco peat mulch + 10% wood vinegar (**T7**), the root length of *H. verticillata* was reduced by 50%. This application rate was the effective dose for 50% (ED50) of the root length inhibition.

Surprisingly, application of coco peat mulch and wood vinegar did not improve weed control in term of root length inhibition where all treatments are likely giving similar results with control, except **T6** (8 t ha^{-1} coco peat mulch + 30% wood vinegar). This finding was in line with a study conducted by Nurshamimi (2018) where the application of coco peat mulch at 8 t ha^{-1} together with 40% curry leaves extract significantly reduce the root length of *H. verticillata* by 90%. These results imply that the combination of coco peat mulch at 8 t ha^{-1} treated with 30% wood vinegar or 40% aqueous curry leaves extract possibly contain high level of allelochemicals or natural compound that leads to a strong reduction in root length.

In contrast, it was found that *H. verticillata* root growth showed minimal injury after treated with **T1-T9** (except **T6**). Likewise, this might be due to the root of bioassay species could had escaped the application of the wood vinegar where coco peat particles can bind wood vinegar and result in lower efficacy. However, coco peat is compatible with wood vinegar after being combined, as the treatment **T7** (12 t ha^{-1} coco peat mulch + 10% wood vinegar) gave 50% reduction on the root growth. This rate is important to determined weed control efficacy by determination of optimum combination of coco peat mulch-wood vinegar doses in order to reduce the application costs.



TO(A) : 4 t ha^{-1} coco peat mulch + 0% wood vinegar

TO(B) : 8 t ha^{-1} coco peat mulch + 0% wood vinegar

TO(C) : 12 t ha^{-1} coco peat mulch + 0% wood vinegar

T1 : 4 t ha^{-1} coco peat mulch + 10% wood vinegar

T2 : 4 t ha^{-1} coco peat mulch + 20% wood vinegar

T3 : 4 t ha^{-1} coco peat mulch + 30% wood vinegar

T4 : 8 t ha^{-1} coco peat mulch + 10% wood vinegar

T5 : 8 t ha^{-1} coco peat mulch + 20% wood vinegar

T6 : 8 t ha^{-1} coco peat mulch + 30% wood vinegar

T7 : 12 t ha^{-1} coco peat mulch + 10% wood vinegar

T8 : 12 t ha^{-1} coco peat mulch + 20% wood vinegar

T9 : 12 t ha^{-1} coco peat mulch + 30% wood vinegar

Figure 4.3: The effect of coco peat mulch treated with wood vinegar on root length of *Hedyotis verticillata*. Vertical bar represent standard deviation (SD) of the mean.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, **T6** (8 t ha^{-1} coco peat mulch + 30% wood vinegar) was found to be the efficient rate in control *H. verticillata* by completely inhibit the emergence, shoot fresh weight and root length of bioassay weed species by 100%. The possibility reason for the inhibitory action of this weed might be due to the presence of the strong active compound in the wood vinegar and the thickness of mulching that provided excellent weed control. These results implied that both wood vinegar and the coco peat mulch are strong weed inhibitors.

5.2 Recommendation

The application of wood vinegar and coco peat mulches as a soil cover is effective in reduce the *H. verticillata* weed infestation under nursery condition, however, further research is needed on the application of wood vinegar and mulches in field condition. This is important in order to elucidate the adsorption-desorption mechanism between wood vinegar and mulch in relation to soil physio-chemical properties.

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APPENDIX A

Figure A.1. *Hedyotis verticillata* weed

Figure A.2. Top soil or media that use for this project

Figure A.3. Wood vinegar that use for this project

Figure A.4. Coco peat that use for this project

Figure A.5. Germinating test of *Hedyotis verticillata*

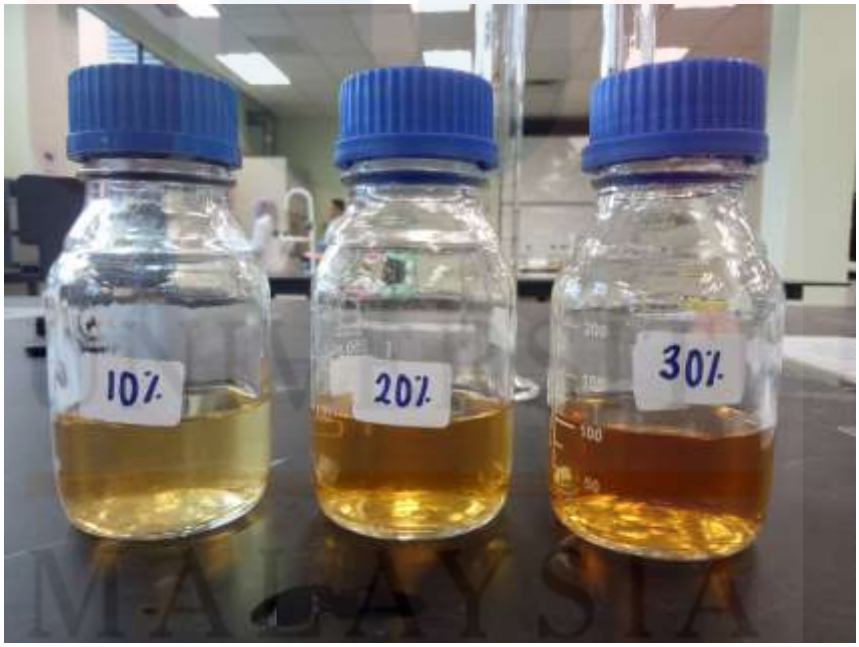

Figure A.6. Treatments of wood vinegar

Figure A.7. Sample of seeds in nursery before application of treatment

Figure A.8. Sample of seeds in nursery after application of treatment

Figure A.9. *Hedyotis verticillata* 4 t ha^{-1} coco peat mulch + 0% wood vinegar after 2 weeks

Figure A.10. *Hedyotis verticillata* 8 t ha^{-1} coco peat mulch + 0% wood vinegar after 2 weeks

Figure A.11. *Hedyotis verticillata* 12 t ha^{-1} coco peat mulch + 0% wood vinegar after 2 weeks

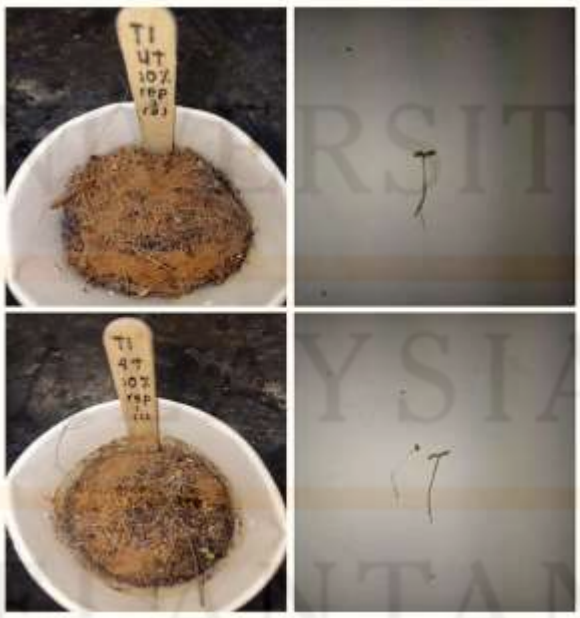

Figure A.12. *Hedyotis verticillata* 4 t ha^{-1} coco peat mulch + 10% wood vinegar after 2 weeks

Figure A.13. *Hedyotis verticillata* 4 t ha^{-1} coco peat mulch + 20% wood vinegar after 2 weeks

Figure A.14. *Hedyotis verticillata* 4 t ha^{-1} coco peat mulch + 30% wood vinegar after 2 weeks

Figure A.15. *Hedyotis verticillata* 8 t ha^{-1} coco peat mulch + 10% wood vinegar after 2 weeks

Figure A.16. *Hedyotis verticillata* 8 t ha^{-1} coco peat mulch + 20% wood vinegar after 2 weeks

Figure A.17. *Hedyotis verticillata* 8 t ha^{-1} coco peat mulch + 30% wood vinegar after 2 weeks

Figure A.18.*Hedyotis verticillata* 12 t ha^{-1} coco peat mulch + 10% wood vinegar after 2 weeks

Figure A.19.*Hedyotis verticillata* 12 t ha^{-1} coco peat mulch + 20% wood vinegar after 2 weeks

Figure A.20.*Hedyotis verticillata* 12 t ha^{-1} coco peat mulch + 30% wood vinegar after 2 weeks

APPENDIX B

Table B.1. Mean value of different rate of coco peat mulch treated with wood vinegar and control treatment on weed emergence (% of control), shoot fresh weight (% of control), root length (% of control) of *Hedyotis verticillata* under nursery condition. (Mean ± standard deviation)

TREATMENTS **Coco peat mulch (t ha^{-1}) + wood vinegar**	**No of weed emergence**	**Shoot fresh weight (mg/plant)**	**Root length (mm/plant)**
4 t ha^{-1} coco peat mulch + 0% wood vinegar	99 ± 30	100 ± 19	100 ± 25
8 t ha^{-1} coco peat mulch + 0% wood vinegar	95 ± 41	100 ± 31	100 ± 64
12 t ha^{-1} coco peat mulch + 0% wood vinegar	100 ± 0	100 ± 0	100 ± 0
4 t ha^{-1} coco peat mulch + 10% wood vinegar	16 ± 7	79 ± 19	27 ± 15
4 t ha^{-1} coco peat mulch + 20% wood vinegar	7 ± 14	75 ± 14	8 ± 18
4 t ha^{-1} coco peat mulch + 30% wood vinegar	7 ± 17	18 ± 33	38 ± 32
8 t ha^{-1} coco peat mulch + 10% wood vinegar	24 ± 58	17 ± 28	87 ± 33
8 t ha^{-1} coco peat mulch + 20% wood vinegar	12 ± 29	63 ± 14	93 ± 89
8 t ha^{-1} coco peat mulch + 30% wood vinegar	0 ± 0	0 ± 0	0 ± 0
12 t ha^{-1} coco peat mulch + 10% wood vinegar	24 ± 19	13 ± 18	50 ± 25
12 t ha^{-1} coco peat mulch + 20% wood vinegar	21 ± 14	13 ± 22	63 ± 34

12 t ha^{-1} coco peat mulch + 30% wood vinegar	15 ± 14	17 ± 26	58 ± 38

ANOVA

Table B.2. ANOVA test result for weed emergence, shoot fresh weight and root length for *Hedyotis verticillata* under nursery condition.

		SUM OF SQUARES	DF	MEAN SQUARE	F	SIG.
WE	Between Groups	60169.713	11	5469.974	7.989	0.000
	Within Groups	31495.667	46	684.688		
	Total	91665.379	57			
RL	Between Groups	86166.646	11	7833.331	6.092	0.000
	Within Groups	46286.667	36	1285.741		
	Total	132453.313	47			
SFW	Between Groups	85030.551	11	7730.050	15.474	0.000
	Within Groups	27974.332	56	499.542		
	Total	113004.882	67			

- **WE** = Weed emergence; **RL** = Root length; **SFW** = Shoot fresh weight

WEED EMERGENCE

Table B.3. Tukey HSD test for weed emergence of *Hedyotis verticillata*

Tukey HSD[a,b]

TREATMENT	N	SUBSET FOR ALPHA = 0.05	
		1	2
T6	9	0	
T2	8	7.5	
T3	8	7.5	
T5	6	11.8333	
T9	3	15	
T1	3	16	
T8	3	21	
T4	6	23.8333	
T7	3	24	
T0 (B)	3		95
T0 (A)	3		99
TO (C)	3		100
Sig.		0.976	1

Means for group in homogeneous subsets are displayed

a. Uses Harmonic Mean Sample Size = 3.963.

b. The group size are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

ROOT LENGTH

Table B.4. Tukey HSD test for root length of *Hedyotis verticillata*

Tukey HSD[a,b]

TREATMENT	N	SUBSET FOR ALPHA = 0.05		
		1	2	3
T6	9	0		
T2	8	7.5	.5	
T1	3	26.6667	26.6667	
T3	3	38.3333	38.3333	38.3333
T7	3	50	50	50
T9	3	58.3333	58.3333	58.3333
T8	3	63.3333	63.3333	63.3333
T4	3	87	87	87
T0 (A)	3		100	100
T0 (B)	4		100	100
T0 (C0	3		100	100
T5	3			126
Sig.		0.102	0.064	0.096

Means for group in homogeneous subsets are displayed

a. Uses Harmonic Mean Sample Size = 3.442.

b. The group size are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

SHOOT FRESH WEIGHT

Table B.5. Tukey HSD test for shoot fresh weight of *Hedyotis verticillata*

Tukey HSD[a,b]

TREATMENT	N	SUBSET FOR ALPHA = 0.05		
		1	2	3
T6	9	0		
T8	7	12.7143	12.7143	
T7	8	13.5	13.5	
T4	7	16.5714	16.5714	
T9	9	17.1111	17.1111	
T3	8	17.75	17.75	
T5	3		62.6667	62.6667
T2	3			75.3333
T1	3			79
T0 (B)	3			99.6667
T0 (A)	5			99.8
T0 (C)	3			100
Sig.		0.987	0.054	0.346

Means for group in homogeneous subsets are displayed

a. Uses Harmonic Mean Sample Size = 3.572.

b. The group size are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.