UNIVERSITI PUTRA MALAYSIA

STUDY ON EFFECTIVE METHOD TO ABOLISH VITEX PUBESCENS VAHL IN LOCAL FRUITS GARDEN, UNIVERSITI PUTRA MALAYSIA, BINTULU SARAWAK CAMPUS

GILBERT MINSIN

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By

GILBERT MINSIN

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ABSTRACT

Vitex pubescens Vahl is a native hardwood tree to Malaysia. *Vitex pubescens* Vahl is considered an invasive tree in agricultural land of UPMKB especially in the local fruits garden. The invasion of *V. pubescens* Vahl disturbs the development of fruits tree and restricts the management practices in the fruits garden. This study decides to test the effective technique to control *V. pubescens* Vahl. There are three techniques involved namely debarking, hack and squirt (triclopyr), and stem injection (triclopyr) were used to evaluate the percentage of foliage loss and stem mortality in the period of five months. This study was conducted in Randomize Complete Block Design (RCBD) where the tree size categorized based on stem diameter (small, medium and large). Collected data was further analysed by using ANOVA and Tukey mean comparison at $\alpha = 0.05$. Hack and squirt method is the most appropriate techniques to control *V. Pubescens* Vahl by achieving high rate of foliage loss and trunk mortality with small-sized tree sample recorded up to 100% loss of leaves, medium-sized tree sample reached 92.5% loss of leaves, and large-sized tree sample achieved 81% loss of leaves. Hack and squirt techniques found to be very effective compared to debarking and injection of stem because of high rate intake of poison penetrated into the bark cells and sapwood of trees. The correct technique helps in controlling the invasive *V. pubescens* Vahl in the local fruits of UPMKB and will help the farm management in the future.

ABSTRAK

Vitex pubescens Vahl adalah pokok berkayu keras yang berasal dari Malaysia. *Vitex pubescens* Vahl dikenalpasti sebagai satu pokok invasif di tanah pertanian UPMKB terutama di taman buah-buahan nadir. Kedatangan *V. pubescens* Vahl mengganggu pembangunan pokok buah-buahan dan menyekat amalan pengurusan ladang di taman tersebut. Kajian ini bertujuan untuk menguji teknik yang berkesan untuk mengawal *V. pubescens* Vahl. Terdapat tiga teknik terlibat yang dinamakan membuang kulit, menetak dan memancut (triclopyr) dan suntikan batang (triclopyr) telah digunakan dalam kajian ini untuk menilai peratusan pengurangan daun dan kematian pokok dalam masa lima bulan. Kajian ini dijalankan dalam Randomize Complete Block Design (RCBD) yang mana saiz pokok dikategorikan berdasarkan diameter batang (kecil, sederhana dan besar). Data yang diperolehi dianalisis dengan menggunakan ANOVA dan Tukey untuk membandingkan mean pada $\alpha = 0.05$. Kaedah menetak dan memancut merupakan teknik yang paling sesuai untuk mengawal *V. Pubescens* Vahl kerana mencapai kadar kehilangan daun dan kematian batang yang tinggi dengan sampel pokok bersaiz kecil dicatatkan mencapai 100% kehilangan daun, sampel pokok bersaiz sederhana mencapai 92.5% kehilangan daun dan sampel pokok bersaiz besar mencapai 81% kehilangan daun. Teknik menetak dan memancut didapati sangat efektif berbanding debarking dan suntikan batang kerana kadar kemasukan racun yang tinggi boleh membunuh sel kulit dan isi kayu gubal pokok. Oleh yang demikian, teknik yang betul membantu dalam mengawal pokok *V. pubescens* Vahl yang invasif di ladang buah-buahan nadir UPMKB dan akan membantu pengurusan ladang pada masa hadapan.

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APPROVAL SHEET

I certify that this research project report entitled "study on effective method to abolish *Vitex pubescens* Vahl in local fruits garden, Universiti Putra Malaysia Bintulu Sarawak Campus" had been examined and approved as a partial fulfilment of the requirement for the degree of Bachelor of Science Bioindustry in the Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus.

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LIST OF ABREVIATIONS

%	Percentage
ANOVA	Analysis of Variance
cm	Centimetres
m	Metre
ml	Millilitre
DBH	Diameter Breast Height
RCBD	Randomize Complete Block Design
TPU	Taman Pertanian Universiti
UPMKB	Universiti Putra Malaysia Kampus Bintulu

CHAPTER 1

INTRODUCTION

1.1. Research Background

Tropical countries have various types of secondary species growth after the land area was cleared. In Malaysia, Leban or *Vitex pubescens* Vahl (Figure 1.1) is one of the common secondary species found everywhere. *Vitex pubescens* Vahl is a native tree species to the region of Malesiana (Kok, 2008). Native plants can be defined for any group of plants that are not introduced by man to a specified area (Kueffer *et al.*, 2004). Basically, *V. pubescens* Vahl is a hardwood tree that can be found growing in the secondary forest, lowland forest, and along the riverbank. In the West Kalimantan, *V. pubescens* Vahl is a species that invade grassland dominated by *Imperata cylindrica* (Oramahi and Yoshimura, 2013). Meanwhile in UPMKB, *V. pubescens* Vahl was found dominant in area where dominated by fern. In term of economic value, *V. pubescens* Vahl is a good source of timber and for the production of charcoal that gives competition to the production of charcoal from the mangrove tree. Besides that, *V. pubescens* Vahl also planted for the purpose of landscape tree along the roadside and shade tree in recreational park. In the other hand, *V. pubescens* Vahl also contains a medicinal value where its leaves and shoot can be used to treat a wound.

In Universiti Putra Malaysia Bintulu Sarawak Campus, *V. pubescens* Vahl is highly invasive in most area especially in the secondary forest and agricultural land. In general, invasive plant species defined by stressing the negative environmental or economic impact of the plants (Alpert *et al.*, 2000; Kueffer *et al.*, 2004; Davis *et al.*, 2000). *V. pubescens* Vahl was found highly invasive in the agricultural area of

UPMKB especially in the local fruits garden. Establishment of local fruit garden allows the germination of *V. pubescens* Vahl seed when the area is cleared for agricultural activities. The local fruit garden area is cultivated with various species of fruits tree particularly fruits tree from Sarawak.

Figure 1.1: *Vitex pubescens* Vahl tree.

The local fruits garden of UPMKB was established since 1986. Basically, this land is more like a collection of local fruits tree of Sarawak. Various species of local fruits were planted in this area such as *Baccaurea macrocarpa*, *Canarium odontophyllum*, *Artocarpus* sp., *Durio zibethinus*, *Nephelium* sp., etc. Since the establishment of local fruits garden 30 years ago, the introduction of various unwanted plant species also occurs. These unwanted plant species are such as *Vitex* tree, *Acacia* tree, various medium-sized tree, shrub, fern, and herbs. In most of the area, *V. pubescens* Vahl is the most invasive and problematic which cause competition to the fruits tree. The invasion of *V. pubescens* Vahl in local fruits garden of UPMKB disturb the development and restrict the management practices in the fruits garden. In addition, this hardwood tree was reported very difficult to control due to re-sprouting ability.

1.2. Problem Statements

1.2.1. Invasion of *Vitex pubescens* Vahl Cause a Problems to Local Fruits of UPMKB.

Vitex pubescens Vahl is an aggressive hardwood tree. This hardwood tree can easily dominate an area due to the aggressiveness to compete with other species. In UPMKB, *V. pubescens* Vahl was found invading the local fruits garden and the invasion cause competition to the crops tree (Figure 1.2). Invasive *V. pubescens* Vahlis competing the fruits tree for space, nutrition, water, and light. Basically, invasive hardwood tree will out-compete crops plants for space, water, nutrition, and light which cause slow development of crops plant. This problem will result in the stunted growth of desirable tree. Moreover, a continuous physical stress will even result to the death of desirable tree.

At the matured growth stage, *V. pubescens* Vahl is able to reach 25 – 35 M tall and crown are often spreading (Chantaranothai, 2011). Competition to gain light could be more difficult for the fruits tree when they are outcompeted by this invasive species. Typically, most fruits tree that affected tends to grow slender stem with small and pointed crown. Basically, this growth feature is not a desirable fruits tree to most farmers. Meanwhile, strong root extension of *V. pubescens* Vahl will out-compete the root extension of fruits tree in search for nutrition. Physical stress through root extension restricts fruits tree from gaining nutrient. As a result, fruits tree will be stunted and no fruiting will occur.

Invasion of hardwood tree is hugely affecting management practice that applied in the fruits garden. The invasion of *V. pubescens* Vahl in local fruits garden of

UPMKB cause ineffective fertilizer application. Any fertilizer that applied for the fruits tree is mostly taken up by this invasive tree. Aggressive root extension of *V. pubescens* Vahl is preventing fruits tree from gaining sufficient food for their growth requirement. As a result, fruits tree are stunted and wasting fertilizer will be the huge problem. This problem will cause a headache to farmers to deal with when throwing money for something that cannot be benefited by the fruits tree.

Figure 1.2: Invasiveness of *V. pubescens* Vahl.

Figure 1.2 is showing the invasiveness of *V. pubescens* Vahl in the fruits garden. The high density of the invasive hardwood tree shades the fruits tree. Most of the fruits tree was highly affected by the dense of *V. pubescens* Vahl canopy because this particular tree is taller than the fruits tree.

1.2.2. Difficulty and Challenges to Control *V. pubescens* Vahl in Fruits Garden.

Vitex pubescens Vahl is able to reach 25 – 35 M tall and crown is often spreading when they are at the matured stage. Since the establishment of local fruits garden 30 years ago, the introduction of *V. pubescens* Vahl was occurred and today they are at the matured growth stage. Physically, this particular size of *V. pubescens* Vahl is very challenging to control since they grow in the fruits garden. There is a various technique which can be applied to control or to abolish *V. pubescens* Vahl, however, the safety of the fruits tree is the number one priority that need to be considered.

Basically, the mechanical method by cutting down the tree is the oldest method that is used to remove the tree in forestry and agriculture. In the modern era, the chainsaw is the famous machine that is used to cut down tree, however, this practice is not a good choice to be applied in the fruits garden. Falling *V. pubescens* Vahl may harm the fruits tree since they are about 25 – 35 M tall. Falling tree will cause major injury to the fruits tree such as broken branches and stem. On the other hand, cutting down *V. pubescens* Vahl in fruits garden require high cost. These particular jobs require a high labour cost since it is totally mechanical work, challenging and risky work.

Chemical application is hugely applied worldwide to control invasive plants. Foliar spraying is one of the common techniques to control weeds which include hardwood tree, shrub, and herbs. This technique involves the use of chemical herbicides and spraying herbicides will kill all the plants that come in contact with the spray. However, herbicide is easily drifted by the wind and will harm the applicator and non-target tree (Lewis, 2007). Foliar spraying is not recommended in the fruits garden since the canopy of target tree is too tall to spray and mix together with the

fruits tree. Foliar spraying can be delivered through an aerial vehicle; however, herbicide is easily drifted by the wind and will harm the fruits tree. In addition, this practice also requires high cost and there is no parameter that helps to prevent fruits tree from herbicide since applicator is unable to control herbicide mist from make contact with the fruits tree.

Basal bark spraying is also a technique to kill hardwood tree by applying herbicide on the trunk base. Basically, this technique is very effective for any hardwood tree that has a thin bark. According to Ditomaso and Kyser (2007), this technique is not recommended to be applied to any hardwood tree that has a thick bark because herbicide is unable to penetrate the tree bark. Even if this practice is being applied, it requires more herbicide in order to increase effectiveness which means more herbicide, cost increase.

V. pubescens Vahl is difficult to control due to the high rate of survival and ability to re-sprout. Most of the technique that is applied by TPU staff is debarking where it is found promotes re-sprouting. Alternative method has to be designed in order guarantee effectiveness yet safety parameter of the fruits tree is the number one priority that has to be considered. By considering the safety of the fruits tree, combination of proper tools, mechanical practice and chemical will promise effectiveness (Manning and Miller, 2011).

1.3. Objectives

The objective of this research is to study the effective method to abolish *Vitex pubescens* Vahl and to determine the respond of *V. pubescens* Vahl on different method applied.

CHAPTER 2

LITERATURE REVIEW

2.1. *Vitex pubescens* Vahl and Its' Characteristics

Vitex pubescens Vahl or Synonym is *Vitex pinnata* L. is a hardwood tree which can be found in most tropics and sub-tropics region (Chantaranothai, 2011). *Vitex pubescens* Vahl was known by the local as leban, leban tanduk, leban buas or kulim papa (Kok, 2008). However, in Borneo, this tree called as Kepapa (Iban), Kelejapak (Kenyah), Kulimpapo or Kuhimpapo (Dusun). This hardwood tree species is belonging to the family of Lamiaceae (Kok, 2008). *Vitex pubescens* Vahl is a species that mostly found grow in open habitats, lowland forest, along the riverbank, and in the secondary forest. It is approximately 300 species of *Vitex* genus that discovered by science in the tropics region (Kok, 2008). Typically, *V. pubescens* Vahl is common in moderate dry regions in lowland forest, especially in open habitats, secondary forest and riverbank. *V. pubescens* Vahl is a pioneer species in *Imperata cylindrical* vegetation or growing in open cluster in the secondary forest (Oramahi and Yoshimura, 2013).

The tree trunk always appear twisted or bent, with the size is up to 70 cm at DBH, bark appear pale grey to yellowish brown with a smooth surface; it appears pale yellow to bright orange at the inner bark (Thenmozhi and Subasini, 2016). Branches are quadrangular and crown often spreading, leaves are compound and arranged opposite with 3 – 5 leaflets, pubescent can be seen below the leaf and petioles (Thenmozhi and Subasini, 2016). Its flower appear whitish blue and inflorescences are terminal panicles; fruits are 5 – 8 mm in diameter and appear black when

ripening (Thenmozhi and Subasini, 2016). The seed of *V. pubescens* Vahl is not germinate under the shade (Kok, 2008).

Vitex pubescens Vahl is a good source of energy where charcoal that made from this tree produce competition to charcoal production from mangrove tree (Orwa, 2009). The stem of *V. pubescens* Vahl is very hard and durable which is very good for the production of timber for construction. In addition, *V. pubescens* Vahl is suitable as ornamental tree which can be planted as shade tree and along the roadside. Moreover, *V. pubescens* Vahl produce medicinal value where its bark and leaves can be used to treat stomach ache, fever, and wound (Orwa, 2009).

2.2. Mechanical Technique to Control Hardwood Tree

Every invasive plant found in any cultivated areas is considered as weed and need to be removed. The invasive tree can be easy to control since they are large and relatively simple to detect, however, the cost of control become high since they are large in size as the ages of tree invasion (Wilgen and Richardson, 2014). Cutting, pulling and damaging tree are some of the manual and mechanical method to control invasive tree that in a small population. This technique can minimize damage to the desirable plants, however, they are generally expensive and time consuming (Tu *et al.*, 2001).

Ring debarking and girdling are the oldest method that is used to remove a tree in forestry and agriculture (Moore, 2013). Ring debarking and girdling is a selective method and cost effective for the control of invasive species in a forest and plantation. Ring debarking or girdling is a technique to abolish hardwood tree by removing stem bark and cambium layer around the trunk. This technique prevents food that produced by the root to travel above debarked and those that produced by the leaves prevented to reach the roots (Moore, 2013).

The main function of tree bark is to provide protection against any external attack and to transport water and nutrient through phloem and xylem tissue. Ring debarking may cause death to the tree due to the internal stress, however, some tree species are able to survive (Delvaux *et* al., 2010). Girdling or ring debarking normally requires less labour compare to cut and remove technique. These techniques are cheaper and only kill the target tree. Success ring debarking will leave standing dead trunk which

is valuable for wildlife habitat and for the source of nutrient in the soil when it decay (Tu *et al.*, 2001).

According to the recent research on hardwood tree, Moore (2013) report that ring debarking promotes flowering and fruiting due to the accumulation of carbohydrates at the tree canopy. Silayo and Kiwango (2010) added that ring debarking or girdling tend to promote sprouting below the cut rings. Debarking and girdling may take 2–5 years to kill a hardwood tree, however, the addition of environmental stress such as drought may speed up mortality and increase effectiveness (Silayo and Kiwango, 2010).

2.3. Combination of Mechanical and Chemical method

In some of the conventional agricultural areas, the effective method for killing those unwanted species of plants is by using the combination techniques mainly using chemicals and mechanical techniques. The purpose of those techniques is to stop the growing processes of the plants from upper part or the lower part. Foliar spraying is one of the common technique to abolish invasive hardwood tree (Lewis, 2007). Foliar spraying will kill all the plants that come in contact with the spray, however, herbicide is easily drifted by the wind and will harm the applicator and non-target tree (Lewis, 2007).

Basal bark spraying is generally suitable for the control of small tree which less than 8 cm in DBH and mostly suitable for woody brush where they are too small for stem injection and too tall for foliar spraying (Nelson *et al.*, 2006). Basal bark spraying is a technique kill hardwood tree by applying herbicide on the trunk base (Miller,

1988). According to the literature that reported by Ditomaso and Kyser (2007), basal bark spraying requires more herbicide compare to other technique. In addition, basal bark spraying technique is not suitable for a hardwood tree with thick bark because herbicide cannot penetrate through the bark. Somehow, Silayo and Kiwango (2010) report that, using herbicide that contains imazapyr through basal bark spraying cause dead zone of one metre around the stem of target tree. It is not recommended to use this types of herbicide if applied via basal bark spraying because it may harm valuable trees around (Bowker and Stringer, 2011; Ditomaso and Kyser, 2007).

Herbicide selection and concentration are very important in order to guarantee effectiveness and to protect the non-target tree, therefore; an optimum amount of herbicide is enough and dilution have to be done if required based on the herbicide label recommendation in order to avoid wasting and pollution (Ford, 2004). Ford (2004) added that, a high concentration of herbicide may cause burn on the target area rather than translocate through the trees. According to Bowker and Stringer (2011) in their research on hardwood tree (*Ailanthus altissima*), glyphosate, triclopyr, picloram, and imazapyr provide a good result to control hardwood tree through various delivery. In addition, Bowker and Stringer (2011) also found that triclopyr, picloram, and imazapyr have a good performance in preventing re-sprouting.

Hughes, Johnson, and Uowolo (2011) in their research on hardwood tree (*Falcatria moluccana*) report that application of triclopyr with crop oil provides good performance where treated tree achieves 98% mortality after a year of treatment. Triclopyr are well known highly effective on broadleaf plant but has low phytotoxicity on grasses (Ganapathy, 1997).

Triclopyr is hugely used in forestry and agriculture to control woody weeds, hardwood trees, and right-of-way management. There are two forms of triclopyr in the market which is; the triethylamine salt and the butoxyethyl ester (Tu *et al.*, 2001). Triclopyr is a synthetic auxin which is a systemic herbicide where mimicking plant growth hormone auxin that cause plant auxin overdose 1000 times from natural levels which cause the disruption of hormonal growth (Ganapathy, 1997). The action of triclopyr initiate at the interior level of the tree, then the exterior effect will be seen later on. Abnormal leaf formation and swelling stem occur within a week after application due to the increase production of ethylene and protein in the plant (Ganapathy, 1997).

Proper application of mechanical and chemical technique can selectively remove individual invasive plants with minimum soil disturbance (Kline and Duquesnel, 1996). Cut surface treatment are including hack and squirt, stem injection, and cut stump technique where involves both mechanical cut and herbicide (Miller, 1988). This technique is highly effective to control both small and large invasive tree, however, this cut surface treatment is not advised for the control of tree that produces latex, exudates or spring sap because it may leach out the applied herbicide (Kline and Duquesnel, 1996).

Stem injection technique and hack and squirt is a popular method that involves making a wound in the woody stem and placing a small amount of herbicide into the wound (Bollig and Zedaker, 1994). Miller (1988) added that stem injection and hack and squirt technique is more selective method to control hardwood tree (more than 10 cm DBH). This particular technique is sometimes less effective in controlling root

suckering as basal bark treatment, however, it is much suitable applied in remote or difficult terrain with minimum damage to the non-target tree (Manning *et al.*, 2011). Badalamenti and La Mantia (2013) added that stem injection and hack and squirt method requires less time to operate and the amount of herbicide used can be minimized. According to Ditomaso and Kyser (2007), the delay between cuttings did not significantly affect the effectiveness.

Picloram and triclopyr are the most famous and most efficient herbicide that being used via stem injection (Bollig and Zedaker, 1994). Bollig and Zedaker (1994) added that all method under the cut surface treatment requires an application of herbicide either diluted or undiluted. According to the recent research on hardwood tree (*Azadiracta indica*), Silayo and Kiwango (2010) report that stem injection with glyphosate also provides effectiveness to abolish hardwood tree.

CHAPTER 3

MATERIALS AND METHODS

3.1. Study Site

The study site is located at N03°12'.55" and E113°4'47.42" and the study was conducted in 4.6 acre plot in local fruits garden Universiti Putra Malaysia Bintulu, Sarawak Campus (Figure 3.1). The local fruits garden of UPMKB was established since 1986 but this area has been abandoned for certain period of time. Therefore, abundant of *Vitex pubescens* Vahl trees is dominated the area. After this campus was reopened in 2002, this area was cleared for local fruits garden of UPMKB for the purpose of teaching, research, and collection of fruits tree. Various species of local fruits were planted in this area such as *Baccaurea macrocapra*, *Canarium odontophyllum*, *Artocarpus sp.*, *Durio* zibethinus, *Nephelium* sp., and many others.

The local fruits garden is one the agricultural area under the supervision of University Agriculture Park Unit (TPU). The ages of fruit trees in the study site approximately around five to eight years old. The local fruits garden land is suitable for any farming activities where the land slope is < 15°. In term of vegetation, the local fruits garden is rich in diversity of herbs plant. Various species of herbs were found growing under the shade of fruit trees. Meanwhile, *V. pubescens* Vahl and *Acacia* sp. are some of the dominant species of hardwood tree but only *V. pubescens* Vahl is found problematic to the fruits garden. The presence of this hardwood tree causes the slow development of fruits tree.

Figure 3.1: Location of the Study Site in UPMKB Area.

The figure 3.1 showing the agricultural land of UPMKB. The University Agriculture Park unit was undergoing agricultural activity such as food-based crop farming, industrial crop farming, freshwater aquaculture, ruminant farming, poultry farming, horticulture, and fruits garden. The study site was located near the TPU office where *V. pubescens* Vahl was found invading the particular area (Figure 3.1). Invasion of this particular hardwood tree cause problem to the fruits garden.

3.2. Methodology

This experiment was conducted in RCBD which is the tree diameter size (DBH) is consider not uniform. The tree was categorized based on the stem diameter (DBH). There is three group of the stem diameter (≤15 cm DBH; small, >15–30 cm DBH; medium and >30 cm DBH; large). The whole experiment requires 90 samples of *V. pubescens* Vahl tree which is 30 trees per treatment and each of the categories of stem diameter size (DBH) have 10 trees.

There is three selected treatment namely debarking, hack and squirt, and stem injection (Table 3.1). Debarking was applied as a mechanical method alone. Meanwhile, hack and squirt and stem injection were applied as a combination of a mechanical and chemical method. In this study, non-treated *V. pubescens* Vahl is considered as a control for the comparison to the treated trees. The details of the treatment presented in a table form below:

Table 3.1: Details of treatment methods.

Treatment method	Location	Treatment date	Herbicide	Carrier	Rate
Non-treated(Control)	Local Fruits Garden UPMKB	14/10/2016	-	-	-
Debarking	Local Fruits Garden UPMKB	14/10/2016	-	-	-
Hack and squirt	Local Fruits Garden UPMKB	28/10/2016	Triclopyr (Garlon*250)	80% water	20%
Stem injection	Local Fruits Garden UPMKB	30/10/2016	Triclopyr (Garlon*250)	80% water	20%

3.2.1. Herbicide Dilution and Calibration

Hack and squirt and stem injection require an application of herbicide. The herbicide used is Garlon*250 (Figure 3.2) which active ingredient of triclopyr butotyl 32.1 %. Triclopyr butotyl is a systemic herbicide that mimicking plant growth hormone (auxin mimicking or synthetic auxin) which cause uncontrolled growth and disrupt plant cell which results to the death of plants (Tu *et al.*, 2001). This herbicide was widely used to control broadleaves weeds and tree. In this study, herbicide was diluted in 1:5 ratio based on the recommendation in the herbicide label. Every 1 ml of herbicide was diluted with 5 ml of water.

Figure 3.2: Herbicide Using Garlon *250.

3.2.2. Debarking Technique

Debarking was applied at 30 cm to 60 cm above the ground depending on the stem size and shape. Debarking was applied by removing tree bark and cambium layer about 20 cm to 50 cm width. The cambium layer was properly removed in order to prevent the bark recovery. Ring debarking was applied by using a sharp machete. There are 30 tree samples of ring debarking which 10 samples for ≤15 cm DBH, 10 samples for >15–30 cm DBH, and 10 samples for >30 cm DBH.

Figure 3.3: Debarking technique.

3.2.3. Hack and Squirt Technique

The hack was made by using axe 30 cm to 60 cm above the ground depending on the stem size and shape. Hack size is based on the axe size which is 8 cm width. Diluted triclopyr herbicide was sprayed immediately into the wound which is four squirts (Approximately 4 ml) for each hack by using calibrated hand held sprayer. There are 30 tree samples treated with hack and squirt which 10 samples for ≤15 cm DBH, 10 samples for >15–30 cm DBH, and 10 samples for >30 cm DBH.

Figure 3.4: Hack and squirt technique.

3.2.4. Stem Injection Technique

The drill hole was made by using gas powered drill machine STIHL brand 25.4 cc with 16 mm diameter of auger bit. Drill hole was made 30 cm to 60 cm above the ground depending on the stem size and shape. Hole was made 45° downward (to avoid herbicide leakage) about 5 cm deep into the stem. The drill hole was made every 8 – 10 cm interval around the stem depending on the shape of the stem. Each of the drill holes was immediately filled with four squirts (Approximate 4 ml) of diluted herbicide (triclopyr). Filling up the drill hole was done with care to prevent overflow in order to avoid waste of herbicide. Later, drill hole was closed by using wooden cork. There are 30 tree samples treated with stem injection which 10 samples for ≤15 cm DBH, 10 samples for >15–30 cm DBH, and 10 samples for >30 cm DBH.

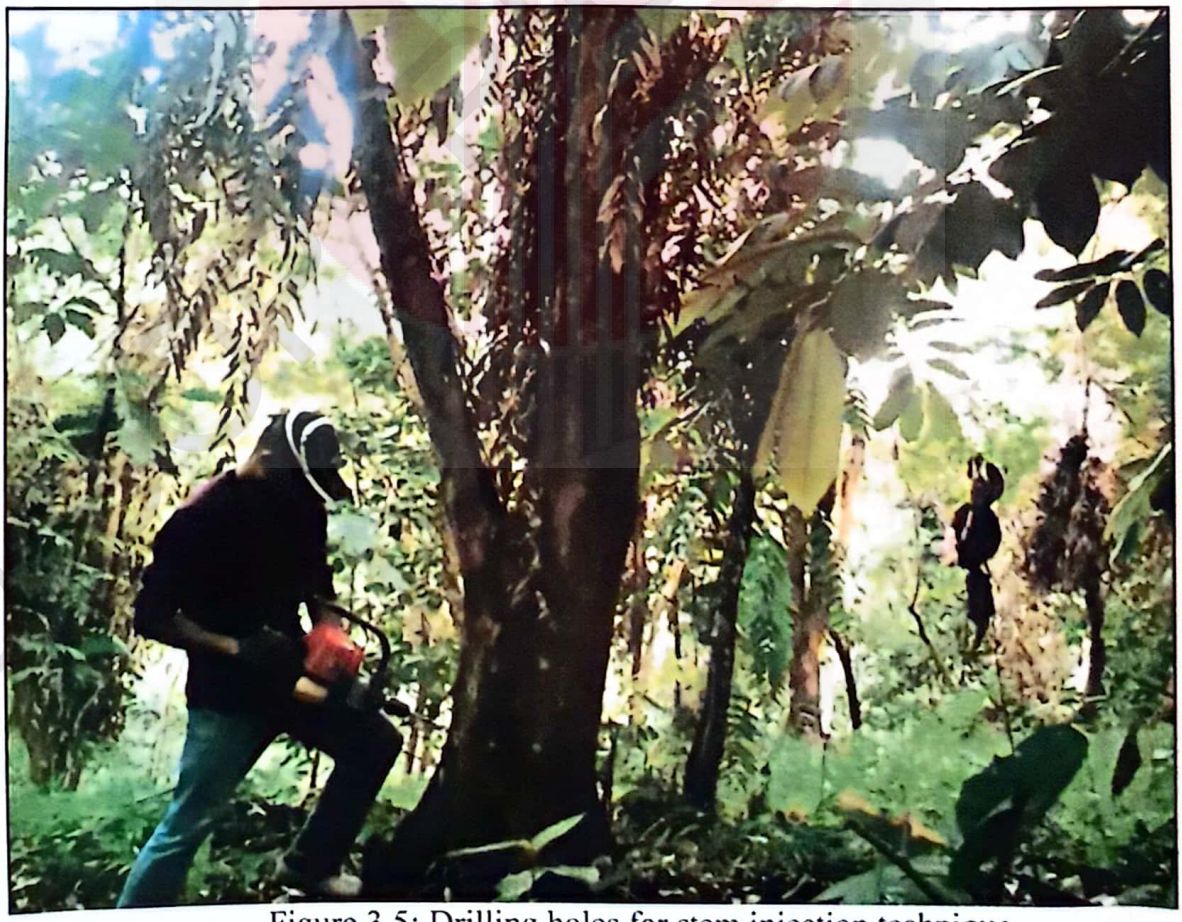

Figure 3.5: Drilling holes for stem injection technique.

3.2.5. Observation Parameter

The observation was conducted within five months which is from October 2016 until March 2017. Treated *V. pubescens* Vahl tree observed visually based on defoliation rate and standing trunk mortality. The percentage of foliage loss was estimated based on the comparison between the healthy tree (control) and treated tree.

Standing trunk mortality was measured in the range of 0 to 5 where 0= alive, 1= alive with 1–3 new sprouts, 2= alive with 4–6 new sprouts, 3= alive with more than 6 new sprouts, 4= dead with new sprouts, and 5= dead without new sprouts. Trunk mortality was evaluated based on the assumption by comparing trunk condition of the non-treated tree (control) and treated tree.

In addition, other visual presence also being evaluated to determine the respond of *V. pubescens* Vahl to the method applied such as bark recovery, formation of flower, and other visual presence.

3.2.6. Data Analysis

The experiment data was statistically analysed by using SAS 9.4 software. Data of percentage of foliage loss was analysed by using one-way ANOVA to determine the significant different of effectiveness of the different treatment applied at $\alpha = 0.05$. Data of trunk mortality also was analysed using one-way ANOVA to determine the significant different among treatment $\alpha = 0.05$. Furthermore, the mean standard error was conducted by running Tukey. The block effect also being counted to determine the influence of stem diameter size (DBH) to the treatment effectiveness.

CHAPTER 4

RESULTS

4.1. Percentage of Foliage Loss

By five months of experiment, treated *V. pubescens* Vahl was evaluated on the percentage of foliage loss. The experiment period was from October 2016 to March 2017. The percentage of foliage loss was estimated on number of foliage loss by comparison between the healthy tree (Control) and treated tree. The percentage of foliage loss was recorded on average according to a number of samples. In addition, the percentage of foliage loss also recorded according to the treatment and the stem size.

4.1.1. Debarking Technique

Debarked *V. pubescens* Vahl was observed on 14 March 2017. All 30 samples were evaluated based on percentage of foliage loss by comparison between debarked tree and non-treated tree (Control) (Table 4.1). The result was recorded according to the stem size category.

Table 4.1: Percentage of foliage loss due to debarking.

Stem size	≤15 cm DBH (Small)	>15–30 cm DBH (medium)	>30 cm DBH (Large)	Overall
No. of sample	10	10	10	30
Foliage loss (%)	54	47.1	43.5	48.2

After five months of experiment, all debarked tree samples achieve overall 48.2% of foliage loss. Debarked tree on the small category was recorded achieve average 54%

of foliage loss. Meanwhile, medium-sized samples recorded average 47.1% of foliage loss. For large-sized tree samples, it has been recorded average 43.5% of foliage loss. According to the result, the small-sized tree sample has achieved the higher percentage of foliage loss however; it does not show huge different to medium-sized and large-sized tree samples.

Figure 4.1: Ring debarked *V. pubescens* Vahl loss 50% of foliage.

The figure above shows approximately 50% of foliage loss on *V. pubescens* Vahl after five months due to debarking. In general, all the debarked tree samples have loss foliage on most branches. Loss of foliage can be seen in most part of the canopy however, the younger part was affected the most where only branches left behind. Approximately, half of the leaves have fallen within five months due to the water stress because debarked area restricts the transfer of water from the roots to the canopy (Figure 4.1).

4.1.2. Hack and Squirt Technique

All tree samples treated with hack and squirt method was evaluated on 28 March 2017. All tree samples were evaluated based on percentage of foliage loss by comparison between treated tree (Hack and squirt) and non-treated tree (Control) (Table 4.2). The result was recorded according to the stem size.

Table 4.2: Percentage of foliage loss due to hack and squirt.

Stem size	≤15 cm DBH (Small)	>15–30 cm DBH (medium)	>30 cm DBH (Large)	Overall
No. of sample	10	10	10	30
Foliage loss (%)	100	96.5	81	92.5

Table 4.2 shown 92.5% overall of foliage loss occur on *V. pubescens* Vahl due to hack & squirt method. It is recorded that all small-sized tree samples have achieved complete defoliation. Similarly, medium-sized tree samples recorded 96.5% loss of foliage where all tree samples achieve from 95% to complete defoliation (Figure 4.2).

Figure 4.2: Fully defoliated *V. pubescens* Vahl.

Meanwhile, the large-sized tree samples recorded 81% of foliage loss. Some of the large-sized tree samples have achieved full defoliation; however, most of the tree samples only achieve approximately 80%–90% of foliage loss due to the larger canopy compare to small-sized and medium-sized tree samples (Figure 4.3).

Figure 4.3: Approximately 80% - 90% foliage loss due to hack and squirt.

4.1.3. Stem Injection Technique

All tree samples treated with stem injection method was evaluated on 30 March 2017. All tree samples were evaluated based on percentage of foliage loss by comparison between stem injected tree and non-treated tree (Control) (Table 4.3). The result was recorded according to the stem size.

Table 4.3: Percentage of foliage loss due to stem injection.

Stem size	≤15 cm DBH (Small)	>15–30 cm DBH (medium)	>30 cm DBH (Large)	Overall
No. of sample	10	10	10	30
Foliage loss (%)	99.5%	24.5	20.5	48.2

After five months, all small-sized trees that injected with triclopyr have achieved full defoliation. All small-sized tree samples have achieved average 99.5% of foliage loss (Figure 4.4). Rapid foliage damage occurred on stem-injected small tree where most of the tree samples achieve complete defoliation. Injection of triclopyr poison *V. pubescens* Vahl and cause huge foliage loss within five months.

Figure 4.4: Fully defoliated *V. pubescens* Vahl due to stem injection.

Somehow, stem injection only results a little damage to the medium-sized and large-sized tree samples (Figure 4.5). Medium-sized tree samples recorded average 24.5% of foliage loss and 20.5% for large-sized tree samples. Foliage loss occurred generally on young leaves mostly at the tip of the branches. There are several consequences that influence the performance of stem injection technique on medium-sized and large-sized tree. Tree size, the amount of herbicide, and depth of drill holes are some of the important factors that influences the percentage of foliage loss.

Figure 4.5: Little foliage damage approximately 20% - 25% of foliage loss.

4.2. Statistical Analysis for Percentage of Foliage Loss

By five months after treatment (October 2016–March 2017), the crown damage of *V. pubescens* Vahl tree was observed. Recorded data were analysed by using SAS 9.4. Data were analysed through ANOVA at α=0.05 to determine the significant different of treatment in term of effectiveness. In addition, mean standard error also being analysed by running Tukey at α= 0.05 as showed in table below:

Table 4.4: Statistically analysed percentage of foliage loss.

Stem size Treatment	≤15 cm DBH (Small)	>15 cm–30 cm DBH (Medium)	>30 cm DBH (large)	Average
Non-treated (Control)	0d	0d	0d	0±0.0d
Debarking	54b	47.1b	43.5b	48.2±2.343b
Hack and squirt	100a	96.5a	81a	92.5±1.708a
Stem injection	99.5a	24.5c	20.5c	48.2±6.833ac

Note: The values are the percentage of foliage loss followed by standard error and letter. Values that followed by the same letter are not different at α= 0.05.

Table 4.4 shows a significant different of effectiveness on percentage of foliage loss among treatment at α=0.05. Non-treated tree (control) remains undamaged. Hack & squirt have been recorded high percentage of foliage loss compare to debarking and stem injection method. Similarly, stem injection on small-sized tree shows a significant similarity of effectiveness to hack and squirt method.

The selection of RCBD for this study was significant at α= 0.05. The performance of stem injection on rate of foliage reduction was highly influenced by the un-uniformity of tree size (Table 4.4). Small-sized tree samples have achieved 99.5% for percentage of foliage loss however; medium-sized and large-sized tree samples only

achieve little foliage damage. Medium-sized tree samples achieve 24.5% for percentage of foliage loss and 20.5% for large-sized tree samples. This data shows that stem injection with triclopyr was effective on small-sized tree but shows poor performance on larger tree. Meanwhile, both debarking and hack and squirt method did not significantly influence by the un-uniformity of stem DBH at $\alpha = 0.05$ (Table 4.4).

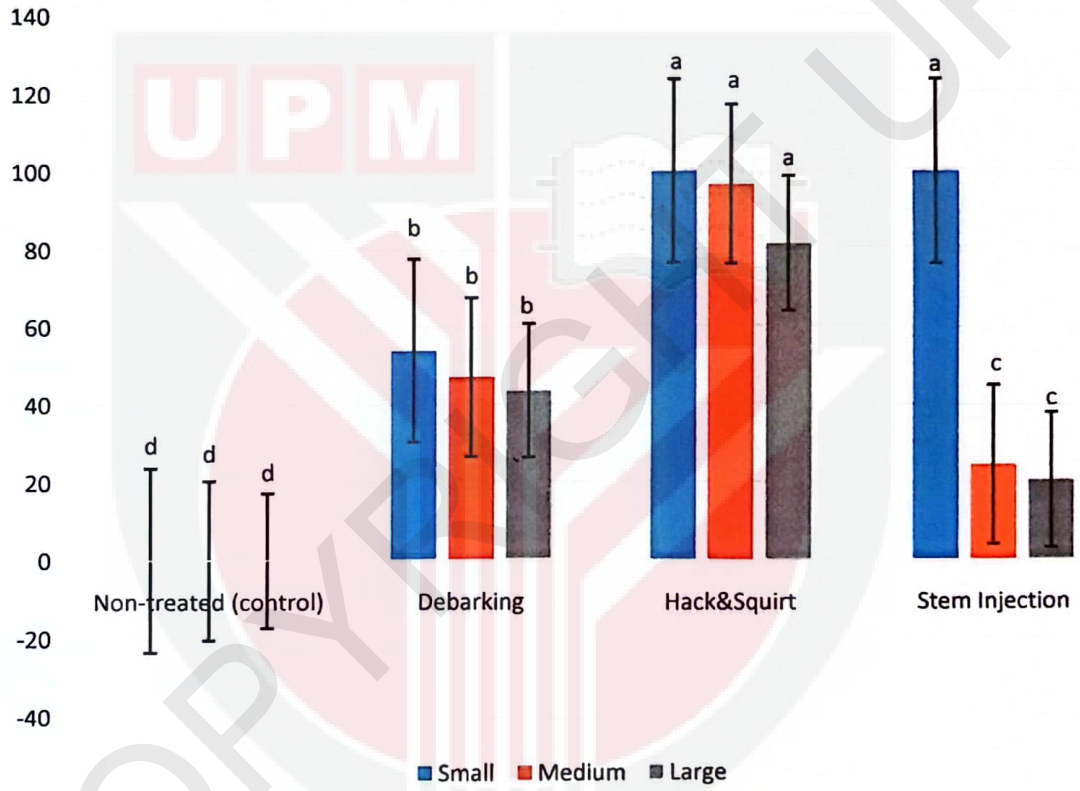

Figure 4.6: Percentage of foliage loss.

Figure 4.6 shows the bar chart of the percentage of foliage loss. Hack and squirt shows a high rate of foliage loss among all the treatment. A small-sized tree sample (100%) has the highest percentage of foliage loss, followed by medium-sized (96.5%) and large-sized tree samples (81%). Meanwhile, debarking shows moderate performance on the percentage of foliage loss. Small-sized tree samples have the highest percentage of foliage loss (54%), followed by medium-sized (47.1%) and large-sized (43.5%). Somehow, the bar chart shows uneven result for stem injection

method. Small-sized tree samples achieve high percentage of foliage loss which is 99.5% however; both medium-sized and large sized tree samples only achieve a little foliar damage. Medium-sized tree achieves 24.5% of foliage reduction while large-sized tree achieve 20.5%.

4.3. Statistical Analysis for Trunk Mortality

Trunk mortality was observed by comparison of trunk condition between treated tree and healthy tree (Control). Trunk mortality was measured in the range of 0 to 5 where 0= alive, 1= alive trunk with 1–3 new sprouts, 2= alive trunk with 4–6 new sprouts, 3 alive trunk with more than 6 new sprouts, 4= dead trunk with new sprouts, and 5= dead trunk.

Statistically, there is a significant different of trunk mortality for all the treatment at α= 0.05. The non-treated tree remains alive. Similarly, stem-injected tree also found alive. Debarked tree was found alive and sprouting occurred below the debarked area. Meanwhile, all *V. pubescens* Vahl that treated with hack & squirt was found dead without any number of sprouting. The variation of stem size (Small, medium and large) did not influence the mortality of *V. pubescens* Vahl at α= 0.05 (Table 4.5).

Table 4.5: Statistically analysed data of trunk mortality.

Stem size Treatment	<15 cm DBH (Small)	>15 cm–30 cm DBH (Medium)	>30 cm DBH (large)	Average
Non-treated (control)	0c	0c	0c	0±0.0c
Debarking	2.1b	2.5b	2.6b	2.4±0.114b
Hack and squirt	5a	5a	5a	5±0.0a
Stem injection	0c	0c	0c	0±0.0c

Note: The values are the stem mortality ranged at 0 - 5 followed by standard error and letter. Values that followed by the same letter are not different at $\alpha = 0.05$.

Hack and squirt method was found effective on trunk mortality of *V. pubescens* Vahl. Small-sized, medium-sized and large-sized tree samples have achieved trunk mortality after five months. The tree trunk was found dead without any number of sprouting. Small-sized tree samples have achieved a full defoliation and standing trunk also found dead. Tree bark can be seen falling apart from the tree trunk. Similarly, a medium-sized tree sample has achieved 96.5% of foliage loss and the tree trunk also found dead (Figure 4.7). Small-sized and medium-sized tree samples were recorded in the range of 5 where standing trunk has achieved mortality.

Figure 4.7: Fully defoliated *V. pubescens* Vahl with dead trunk

Meanwhile, large-sized tree samples have achieved 81% of foliage loss through hack and squirt technique, however, the trunk was found dead (Table 4.5). A small number of foliage is still can be seen on the tree canopy but, it is not preventing mortality (Figure 4.8). The tree trunk was consider dead by comparison to the trunk condition of non-treated tree (Control). Tree samples from large-sized were recorded in the range of 5 where standing trunk was dead without any number of new sprout.

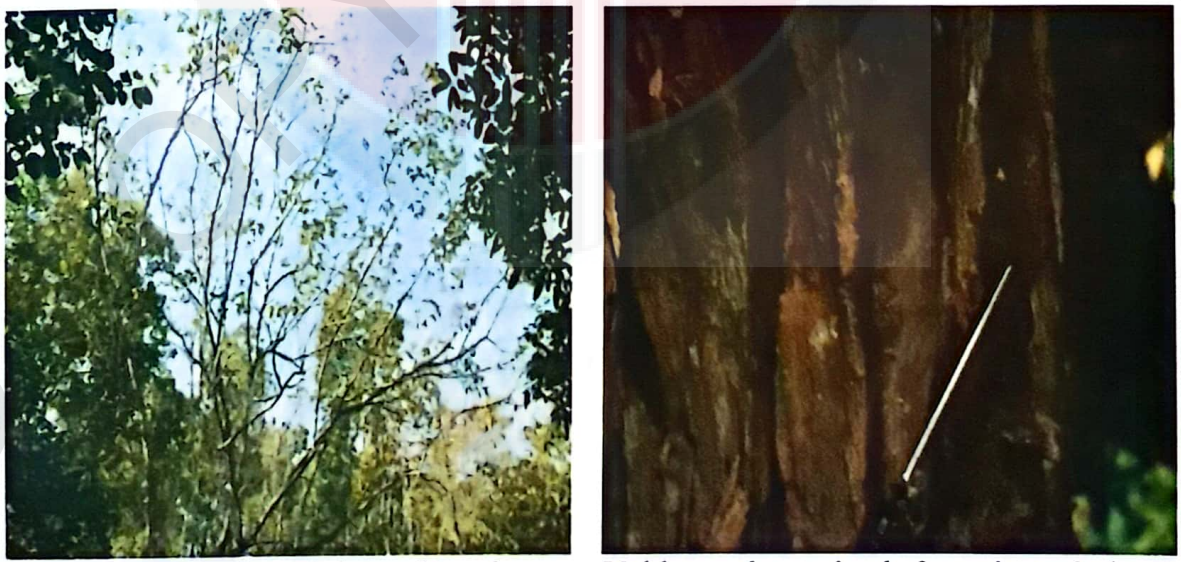

Figure 4.8: Dead trunk large *V. pubescens* Vahl tree due to hack & squirt technique.

Debarking technique was found poor performance on trunk mortality. Small-sized tree samples were recorded at the range of 2 where trunk is still alive and 4 – 6 new

sprouts were found below the debarked area (Table 4.5). Meanwhile, medium-sized tree samples and large-sized tree samples were recorded at the range between 2 and 3 where standing trunk still alive and new sprouts were found approximately 7 – 9 below the debarked area (Table 4.5).

Figure 4.9: Alive debarked tree with new sprout below the debarked area.

In the perspective of debarking technique, 20 cm of the debarked width was found enough to prevent bark recovery (Figure 4.10). Within five months, *V. pubescens* Vahl was failed to recover the debarked area, therefore; it will give a long term pressure to the tree. According to Silayo and Kiwango, (2010) debarking technique on hardwood tree may take two to five years to kill tree however, the addition of environmental stress will increase effectiveness. *V. pubescens* Vahl may achieve mortality in the long term caused by restricted translocation of water and food due to the loss of bark and cambium layer.

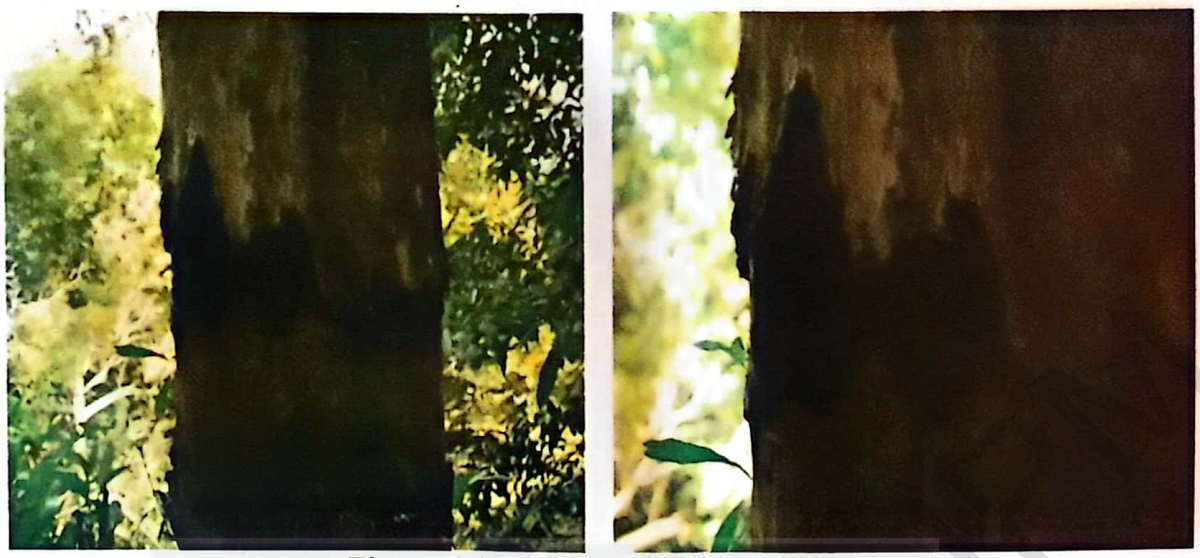

Figure 4.10: 20 cm of debarked area.

Stem injection with triclopyr was found different in term of trunk mortality compare to hack and squirt and debarking technique. Injected small tree samples has achieved complete defoliation, however, the defoliated standing trunk left alive (Figure 4.11). Somehow, injected large tree (> 15 cm DBH) was found only achieve 20% - 25% of foliage loss (Table 4.4). A small tree was recorded in the range of 0 for trunk mortality where standing trunk are still alive but no number of new sprout was found (Table 4.5). Similarly, both medium and large tree samples were found alive and recorded in the range of 0.

Figure 4.11: Defoliated *V. pubescens* Vahl due to stem injection but trunk is still alive.

CHAPTER 5

DISCUSSION

5.1. Appropriate Method for Abolishment of *V. pubescens* Vahl

In this study, hack and squirt technique were found highly effective to control *V. pubescens* Vahl in the local fruits garden of UPMKB. This is because all treatments in different stems size were shown the percentage of foliage loss more than 81% in five months. The combination of mechanical technique and herbicide were found a high rate of foliage loss and stem mortality within five months of treatment. Hack cut around the trunk give physical stress to the tree while the applications of triclopyr poison the tree due to the uncontrolled growth. (Tu *et al.*, 2001) explain that triclopyr is an auxin mimic herbicide which is mimicking plant growth hormone which causes uncontrolled growth where result to the death of target tree.

Table 5.1: Percentage of foliage loss.

Stem size / Treatment	≤15 cm DBH (Small)	>15 cm–30 cm DBH (Medium)	>30 cm DBH (large)	Average
Non-treated (Control)	0d	0d	0d	0±0.0d
Debarking	54b	47.1b	43.5b	48.2±2.343b
Hack and squirt	100a	96.5a	81a	92.5±1.708a
Stem injection	99.5a	24.5c	20.5c	48.2±6.833ac

Note: The values are the percentage of foliage loss followed by standard error and letter. Values that followed by the same letter are not different at $\alpha = 0.05$.

The high overall of foliage loss with 92.5% occurs on *V. pubescens* Vahl due to hack and squirt method. It is recorded that all small-sized tree samples have achieved complete defoliation. Similarly, medium-sized tree samples recorded 96.5% loss of foliage where all tree samples achieve 95% to complete defoliation. Meanwhile, the

large-sized tree samples recorded 81% of foliage loss. Some of the large-sized tree samples have achieved full defoliation; however, most of the tree samples only achieve approximately 80%–90% of foliage loss due to the larger canopy compare to small-sized and medium-sized tree samples. In general, hack and squirt method cause a rapid foliage loss. Mechanical cut and application of herbicide poison the tree which results to the extreme foliar damage.

Hack and squirt techniques found to be very effective compared to debarking and injection of the stem because of high rate intake of poison penetrated into the bark cells and sapwood of trees. Hack cut that made around the tree result to the high rate of poison intake through plant vascular bundles especially through the phloem. Unlike stem injection technique, poison is effectively penetrated into the bark cell by hack and squirt technique because herbicide is applied directly to the active food transportation in the bark cells. In addition, the hack cut around the tree stem also increase the effectiveness of poison penetration due to a wider area of cut which means the more cut, the higher rate of poison intake.

Table 5.2: Standing trunk mortality.

Stem size / Treatment	<15 cm DBH (Small)	>15 cm – 30 cm DBH (Medium)	>30 cm DBH (large)	Average
Non-treated (control)	0c	0c	0c	0±0.0c
Debarking	2.1b	2.5b	2.6b	2.4±0.114b
Hack & squirt	5a	5a	5a	5±0.0a
Stem injection	0c	0c	0c	0±0.0c

Note: The values are the stem mortality ranged at 0 - 5 followed by standard error and letter. Values that followed by the same letter are not different at $\alpha = 0.05$.

Hack and squirt technique was found highly effective on trunk mortality compare to debarking and stem injection technique (Table 5.2). Tree samples that treated with hack and squirt were found achieve mortality in all tree size categories. All the tree samples were recorded in the range of 5 where trunk is dead and no new sprouting occurs. Hack and squirt technique is found effective to control re-sprouting ability of *V.pubesecns* Vahl compare to debarking technique. The application of triclopyr results to a devastating damage to the living cells of *V. pubescens* Vahl which prevent re-sprouting.

Hughes, Johnson, and Uowolo (2011) in their research on hardwood tree (*Falcatria moluccana*) report that application of triclopyr with crop oil provides good performance where treated tree achieves 98% mortality after a year of treatment. Similarly, this study on *V. pubescens* Vahl also found treated tree achieve more than 90% of mortality. In addition, Badalamenti and La Mantia (2013) added that hack and squirt method requires less time to operate and the amount of herbicide used can be minimized.

5.2. Respond of *V. pubescens* Vahl on Different Method of Abolishment

5.2.1. Debarking Promotes Re-sprouting

Debarking technique promotes sprouting below the debarked area. Standing trunk was found alive with 4 - 9 numbers of new sprouts around the trunk below the debarked area (Table 4.5). Silayo and Kiwango, (2010) report that debarking technique on hardwood tree tend to promote sprouting below the cut ring. Likewise, this study on *V. pubescens* Vahl also found that debarking technique promotes sprouting. The ability of *V. pubescens* Vahl to re-sprouts will become another challenge to control this hardwood tree. In the perspective of technique, debarked *V. pubescens* Vahl was found failed to recover 20 cm of the debarked area (Figure 4.10). Swelling was appeared above the debarked area due to the accumulation of food that produced from the leaves which are prevented to reach the roots. After five months, swelled bark above debarked area was disrupted due to the uncontrolled level of carbohydrates accumulation. The disruption of swelling bark increases the width of debarked area into a few centimetres.

Debarking method is not really effective to kill this hardwood tree; however, this technique is still an alternative if other technique is not available. To improve the effectiveness of debarking, it was advised that new sprout must be removed frequently so that it will give more stress on the tree in the long term. In addition, any sign of bark recovery should be removed. Debarking is less expensive in term of labour and it provides mobility to the applicator especially in a remote area. In the long term, loss of foliage, removing new sprouts, and preventing bark recovery will kill this hardwood tree. According to Silayo and Kiwango (2010), debarking technique on hardwood tree may take two to five years to kill tree, however, addition

of environmental stress will increase effectiveness. *V. pubescens* Vahl may achieve mortality in the long term caused by restricted translocation of water and food due to the loss of bark and cambium layer.

5.2.2. *V. pubescens* Vahl Respond to Hack and Squirt

In this study, hack and squirt technique were found highly effective on both foliage loss and trunk mortality. The combination of mechanical technique and herbicide was found successfully kill the tree within five months of treatment. Hack cut around the trunk give physical stress to the tree while the applications of triclopyr poison the tree due to the uncontrolled growth. Tu *et al.*, (2001), explain that triclopyr is an auxin mimic herbicide which is mimicking plant growth hormone which causes uncontrolled growth where result to the death of target tree. *V. pubescens* Vahl were found swelling and producing callus-like along the stem by one week after treatment and all those callus-like were disrupt within one month which is followed by the loss of foliage (Figure 5.1). Swelling and formation of callus-like along the stem occur due to the increase of ethylene and protein (Ganapathy, 1997).

Figure 5.1: *V. pubescens* Vahl respond to Triclopyr through hack and squirt.

After a month of treatment, callus-like along the stem was disrupts and tree bark along the stem are rotting. This extreme damage was caused by uncontrolled growth which disrupts the tree metabolism balance. The application of triclopyr generally disrupts most of the functional tissue of the tree which causes the death of *V. pubescens* Vahl.

5.2.3. Poor Performance of Stem Injection to Large Tree

Stem injection method was found poor performance on a larger tree. Larger tree samples (>15 – 30 cm DBH; medium and >30 cm DBH; large) recorded very little foliage damage after five months of treatment. Somehow, small tree was recorded vulnerable to stem injection. Most of the tree samples recorded achieves complete defoliation; however, trunk mortality did not achieved. This standing trunk is still alive after the five months of treatment but, there is no single number of new sprouts found

Economically, stem injection is a costly technique compare to debarking and hack and squirt technique. This technique requires heavy equipment compare to debarking and hack and squirt method. Unlike debarking and hack and squirt, stem injection technique restrict mobility of applicator especially in a remote area. Drilling a hole around the tree stem involves the use of drill machine which gives additional cost where drill machine is generally expensive. In addition, gas-powered drill machine that being used requires fuel in order to operate which is another expenses that need to be paid. Thus, unlike debarking and hack and squirt technique, stem injection clearly costly yet not really effective.

5.3. Requirement for Further Study

In this study, the amounts of herbicide were not being studied in the different amount in both hack and squirt and stem injection technique. It is four squirts (Approximately 4 ml) of herbicide being applied for every 8 cm incision in hack and squirt technique. Similarly, drill holes for stem injection technique were also filled with four squirts (Approximately 4 ml) of herbicide. Therefore, further study in the different amount of herbicide is required in order to determine the effective amount of herbicide that can give killing effectiveness to the target tree. This aspect is important in order to increase effectiveness, avoid waste of herbicide and reduce a cost for herbicide.

Hack and squirt and stem injection were not being studied by using different types of herbicide. Further study is required to determine the effectiveness of this technique in different types of herbicide. Triclopyr which is being used in this study was found effective through hack and squirt technique, however, less effective through stem injection technique. Therefore, further study on different type of herbicide should be taken in future in order to determine the best herbicide applied especially through stem injection technique.

Moreover, stem injection was not being studied in different depth of drill holes. The drill holes depth is made 5 cm for this experiment. Stem injection technique was found poor performance on large tree (> 15 cm DBH). The drill holes depth is one of the possible factors that influence the poison translocation into tree sapwood. Therefore, further study on different drill holes depth should be taken in future in order to determine the best drill holes depth especially for large tree (> 15 cm DBH).

CHAPTER 6

CONCLUSION

Vitex pubescens Vahl is found anywhere in UPMKB as invasive tree in the agricultural land especially in the local fruits garden. The invasion of abundant *V. pubescens* Vahl is effecting the development of fruit trees and restricted the management practice in the fruits garden. This is because this species is difficult to be abolished from the farm land due to its good survival characteristics and also the rich of dispersal source in this campus. In this study, hack and squirt method was found highly effective to control *V. pubescens* Vahl. This technique results to high rate of foliage loss percentage and trunk mortality. Small-sized tree samples were recorded achieved 100% foliage loss, medium-sized tree samples achieved 92.5% foliage loss, and large-sized tree samples achieved 81% foliage loss. Further study is required to determine the effectiveness in different type of herbicide for both hack and squirt and stem injection. Furthermore, the amount of herbicide also requires further study in different amount of herbicide in order to determine the least amount of herbicide that can kill target tree. In addition, the drill holes depth in stem injection technique also requires further study to determine the level of effectiveness in different holes depth. As a recommendation, hack and squirt is highly advised for the control of invasive *V. pubescens* Vahl due to high level of effectiveness and cost effective. The study of these techniques were beneficial for agricultural practices in the future in order to control any invasive hardwood trees and can be applied by the farmer locally especially in Sarawak.

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PUBLICATION OF THE PROJECT UNDERTAKING

This is to certify that I have no objection to publish the project entitled "study on effective method to abolish *Vitex pubescens* Vahl in local fruits garden, Universiti Putra Malaysia Bintulu Sarawak Campus" by the supervisor in a joint authorship. However, it has to be evaluated by the Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus and published in the form approved by the Faculty.

Gilbert Minsin

Date: 19/7/17