BINDURA UNIVERSITY OF SCIENCE EDUCATION

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DEPARTMENT OF NATURAL RESOURCES

EFFICIENCY EVALUATION OF TWO HERBICIDES FOR THE ERADICATION OF *VERNONANTHURA POLYANTHESE* WEED IN FOREST PLANTATIONS.

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DEDICATION

To my late mother Mrs M. Jamu, my gorgeous father Mr T. Kadyadhori "Bass Temba" and the beautiful and caring wife Joyce Simbarashe Dube as well as my lovely daughter Shalom Tadiwanaishe Kadyadhori.

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ABSTRACT

The weed, (*Vernonanthura polyanthese*), is a plant species of global importance in beekeeping. In Zimbabwe, management of the weeds is mainly based on the use cultural methods and some herbicides that have been rumoured to kill the weed. However, herbicide use has several adverse effects including increased cost of production, herbicide resistance, negative impacts to human health and the environment. The present study investigated an alternative control approach to *Vernonanthura polyanthese* that applied the herbicides as hand spraying. A field experiment was conducted at Cashel estate Chimanimani during the 2021-2022 summer season to evaluate the efficacy of two herbicides applied as chemical treatment for the control of *Vernonanthura polyanthese* in forest plantation. The trial was set up as a randomized experimental design with three treatments. Data for severity and weed incidence was collected three times at seven-day intervals starting from 14 days after spraying. The herbicide that performed the worst was roundup, which had a higher average severity and percentage increase than the other herbicide (triclopyr). Triclopyr can be used by foresters for *Vernonanthura polyanthese* control if its efficacy is validated after additional research since it killed about 80% of the sprayed weeds if not stems.

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LIST OF ACRONYMS AND ABBREVIATIONS

ATZ	- Allied Timbers Pvt Limited
BUSE	-Bindura University of Science Education
V. polyanthese	-*Vernonanthura polyanthese*

CHAPTER 1: INTRODUCTION

1.1 Background to the study

Vernonanthura polyanthese weed dominated the Tandaai estate in 2001; it came from Mozambique by Cyclone Eline. An invasive weed that can easily spread and dominate land is what it is. The weed grows fast and suppresses the growth of pines, farm crops, and grass for grazing. (Tomkins 2002) stated that, "weed control in plantations and woodlots is crucial during the first 2 growing seasons. Without adequate weed control, competition for water, nutrients, and light can lead to high early mortality of trees. The slow growth of surviving trees is inevitable if weeds are not controlled." The seeds are wind-dispersed and during fires, they cause spot fires.

With special reference to Mudima plantation forest, Allied Timbers, several mechanical procedures such as burning and slashing have been used but have failed to remove the weed. Garlon chemical was unsuccessfully utilized by Mudima estate's neighboring plantation enterprise Ifloma in Mozambique. However, the effectiveness of two herbicides, TRICLOPYR 480 EC and ROUNDUP, in eliminating the invasive weed was investigated in this study. According to the Nature Conservancy, 2004, Roundup "is a non-selective herbicide used for the control of a broad range of weeds including terrestrial annual and perennial grasses and broadleaved herbs, woody species, and riparian and emergent aquatic species." According to Dow Agro Sciences," vegetation managers and foresters use triclopyr herbicide from Dow Agro Sciences to control woody plants, annuals and perennial broadleaf weeds in forests, grass pastures, rangeland, rights-of-way, and in non-crop areas and ornamental Turf, industrial sites and non-irrigation ditch banks. The main difference between Triclopyr and Glyphosate is that triclopyr kills only broadleaf plants (non-grassy plants), while Glyphosate kills all plant species. Triclopyr is a selective herbicide that kills broadleaf weeds, ivy, and woody plants, and it does not harm grasses.

Plantation establishment at Tandaai estate has been deprived by the *Vernonanthura polyanthese* weed. The weed has affected planted compartments in terms of survival percentage, and growth due to suppression. *Vernonanthura polyanthese* has delayed land clearing and weeding operations in areas it has dominated due to its intensity therefore, there is a need of the effective eradication of the weed.

1.2 Problem statement

The weed *Vernonanthura polyanthese* has affected planted compartments by causing early mortality in young trees and has delayed land clearing and weeding operations in areas it has dominated due to its intensity as well as causing spot fires during winter season. Coming to communal lands has caused serious problems for farmers since it dominates any open space leading to the loss of land for farming as well as a grazing area for animals. This is causing negative effects on timber production as well as agricultural activities at large in Chimanimani.

Allied Timbers has been trying several mechanical methods such as burning, complete (manual) weeding, and slashing of the weed but no positive results yielded. Due to the above problem, there is a motive to come up with a solution using triclopyr chemical control method against roundup chemical for the eradication of *V. polyanthese.*

1.3 Justification

The weed spreads very fast soon after any disturbance like fire. This happens to delay the silviculture operations such as complete weeding as well as causing spot fires during fire seasons and high mortality rate soon after planting. This calls for research to find out the best way of eradicating the invasive weed.

1.4 Aim

The aim of this study was to investigate the efficacy of Triclopyr and Roundup as chemical herbicides for *Vernonanthura polyanthese* management in plantations.

1.4.1 Objectives

To compare the time taken by each herbicide to kill the weed.

To compare the cost of operation using each herbicide.

To assess the percentage of the weed killed by each chemical.

1.4.2 Hypotheses

There is no significant difference between the use of roundup and triclopyr as chemicals for the control of *Vernonanthura polyanthese* weed.

There is significant difference between the use of roundup and triclopyr as chemicals for the control of *Vernonanthura polyanthese* weed.

CHAPTER 2: LITERATURE REVIEW

2.1 Taxonomy of the invasive weed

Kingdom	: Plantae
Phylum	: Magnoliophyta
Division	: Angiosperm
Class	: Magnoliopsida
Order	: Asterales
Family	: Asteraceae
Genus	: *Vernonanthura*
Species	: *polyanthese*
Name in the public domain	: Mupesepese
	: Bee bush (Dematteis)

Table 2. 1 Species record and details

Species Name	*Vernonanthura Polyanthese*
Common Name	Mupesepese
Status	Introduced
World distribution	Native from Brazil (Indigenous shrub in Brazil)
Description	• Up to 4m tall shrub or small tree • Species introduced as a nectar plant for bees in Mozambique.
Habitat	Secondary vegetation is common in disturbed regions, especially those affected by fire.
Altitude	345m – 1710m
Zimbabwe distribution	Eastern highlands bordering Mozambique

2.2 *Vernonanthura polyanthese*

The shrub *Vernonanthura polyanthese* is native to Bolivia and Brazil (Vega & Dematteis, 2014). The new report of *V. polyanthese* in Zimbabwe is the first time the species has been discovered outside of its natural region. Although Hyde et al. (2016, sub-*V.phosphorica*) reported the introduction of the species in Mozambique in the 1990s to increase honey production, as is the case in Brazil, where *V.polyanthese* is a well-known honey plant pollinated by bees, no existing herbarium specimens of *V. polyanthese* collected in Zimbabwe or neighbouring countries could be traced (Lorenzi 2000).

They discovered colonies of *V. polyanthese* near the towns of Chimanimani, Mutasa District, Chipinge, and Mutare during recent fieldwork in the eastern region of Zimbabwe, where it has become established, naturalized, and invasive (definitions for naturalized and invasive are after the fact) (Blackburn et al., 2011). *V. polyanthese* flowers in Zimbabwe from June to August and subsequently produces a large number of wind-dispersed fruits, as seen in appendices 2 and 3. At elevations ranging from 345 to 1710 meters, it can be found in disturbed regions, along the roadside, in secondary vegetation, pine plantations, dry forest, and riparian forest margins. Because of its invasiveness in Zimbabwe and ease of dissemination by wind (Ishara & Maimoni-rodella, 2011), the species is likely to spread to other African countries.

Robinson, who isolated the representative of Vernonia Schreb, erected the genus *Vernonanthura* with *Baccharis brasilian L*. as the type. This is the first time I've heard of this new genus. *Vernonanthura* includes 70 species having a shrubby or tree-like habit in its current range. Its focus is on South America, particularly in south-eastern Brazil (Robinson, 1992). *Vernonanthura polyanthes*e was previously known as *Vernonanthura phosphoric*, which was derived from *Chrysocoma phosphoric*.

Figure 2. 1 Picture of *Vernonanthura polyanthese*

2.2.1 Distribution of *Vernonanthura polyanthese* in Zimbabwe

After being introduced from Brazil to Mozambique, *Vernonanthura polyanthese* has grown established, naturalized, and invasive in the Vumba regions, Chimanimani, Chipinge districts, and Mutasa district in Mutare, posing a new issue in the Eastern Highlands (Timberlake et al., 2016). It prefers disturbed and burned habitats under wattle, blackwood, pines, and eucalyptus, according to studies.

2.2.2 Dispersal of *Vernonanthura polyanthese*

Vernonanthura includes 70 species having a shrubby or tree-like habit in its current range. Hyde et al (2016 sub-*Vernonanthura phosphorica*) reported the introduction of the species in Mozambique in the 1990s to increase honey production, similar to the case in Brazil where *V. polyanthese* is a well-known honey plant pollinated by honey bees (Robinson, 1992). (Lorenzi

2000). From June to August, *V.polyanthese* blooms and produces a large number of wind-dispersed fruits. At elevations ranging from 345 to 1710 meters, it can be found in disturbed regions, along roadsides, in secondary vegetation, pine plantations, dry forests, and riparian forest margins.

2.2.3 Management of *Vernonanthura polyanthese*

Weed control is difficult due to weed populations' ability to vary geographically and temporally, as well as their ability to adapt fast to novel management and control tactics (Sosnoskie et al., 2018). Allied Timbers Zimbabwe has tried a variety of approaches, including burning, total (manual) weeding, and weed slashing, but has had no success. Chemicals such as garlon, a systematic chemical, have been used in the past, but to no avail. The garlon was only able to keep the weed at bay. Chemical control measures such as the use of triclopyr, on the other hand, are still in the experimental stage. Triclopyr can kill woody species like *V. polyanthese*, so it's important to test it.

2.2.4 General Effects of *Vernonanthura polyanthese*

Most changes in species composition reflect changes in soil water and nutrient availability and changes in the availability of essential plant resources such as light, nutrients and water may result in a change in vegetation community composition (Clegg, 1999)(Clegg, 1999). Nutrient dynamics may become altered as a result of changes in the physical properties of the soil caused by the introduction of an alien species such as *Vernonanthura polyanthese.*

2.2.5 Effects of *vernonanthura polyanthese* on Agriculture

At a stakeholder consultative meeting in November 2019 in Harare, Environmental Management Agency spokesperson Liberty Mugadza stressed that there was a need to put in place measures to deal with the invasive plant. The plant is said to be affecting indigenous plant populations depriving communities of the benefits they have been getting from flora, including medicines and food. Mr. Mugadza claims there is evidence that *V. polyanthese* has more potential of spreading into the entire country through wind action. It is a serious weed also affecting livelihoods in the Eastern Highlands where tea plantations, fruit orchards, timber plantations, and tourism is practiced. In an interview with the Forestry Commission acting deputy general manager (research and training), Joyce Gombe mentioned that the plant was affecting the forestry business. "It is a problem for us interested in forestry and bio-diversity. It has proven to be a serious challenge in silvicultural operations in the plantations and that has increased our costs and we look forward to a solution to the problem," she said.

2.3 Development of Chemicals

Chemical weed management has been utilized for a long time, starting with sea salt, industrial by-products, and oils. Copper and iron sulphates and nitrates were tried, with sulphuric acid proving to be significantly more effective. In 1896, France created Sinox, the first important organic chemical herbicide. In the late 1940s, new herbicides were produced as a result of World War II research, ushering in the era of "wonder" weed killers. Over 100 new compounds were synthesized, produced, and put into use in just 20 years. In terms of economic impact, chemical weed management outperformed both plant disease and insect pest control. The year 1945, in particular, was pivotal in the development of selective chemical weed control. 2, 4-D (2, 4-dichlorophenoxyacetic acid), 2,4,5-T (2,4,5-trichlorophenoxyacetic acid), and IPC (Isopropyl-N-phenyl carbamate) were introduced at the time—the first two as foliar sprays against broad-leaved weeds, the third as a soil application against grass species (ENCYCLOPDIA BRITANNICA).

However, Dawkins (1953) for many years the chemical which was being used was sodium arsenate which was applied as an aqueous solution or paste to a circular-cut or girdle which allowed access to the conduction tissues. Sodium arsenate had a disadvantage of high toxicity towards man and animals until the introduction of growth regulating herbicides 2.4D and 2.4.5-T which were safer. These two chemicals were mixed with used motor oil and applied around a ring of the tree trunk; this gave good results as most trees were killed. Diesel oil was later found to be a better diluent with some resistant species. Dawkins found out that 2.4D and 2.4.5-T chemicals were very effective as they were systemic and could control a wide range of woody species. Julian Evans (1992) also commented that 2.4 –D mixed diesel oil or paraffin (kerosene) gave good results to control stump growth but was also very costly and hazardous to both health and the environment.

Despite the fact that herbicides are frequently used in forestry, there are additional benefits to employing them. Some herbicides are non-selective, according to Joshua Duvauchelle (2017). This means that the toxins harm all plants, not just weeds. Gardeners should avoid spraying non-selective herbicides on plants they want to keep when using them. Furthermore, applications should be avoided when it is windy, as the herbicide spray may travel into non-target plants due to the breeze. Weed resistance to a particular pesticide might develop after repeated application. If the weeds become resistant, they will no longer respond to the herbicide's active ingredients. Kimber (1976) stated that the major problem associated with the use of the chemical was the risk of desirable trees being injured through root uptake (residual herbicides). Julia Evans (1992) also agreed that herbicides though they are cheap and effective are poisonous and must be used with due care, particularly if the chemical contains heavy metals such as arsenic pentoxide which has been widely used for killing trees. Herbicides must also be stored, mixed, and applied with care in order to be used properly and at the correct rates while also reducing the risk to the environment. Chemicals and application equipment are typically imported, and the effects on vegetation management and residual activity are unknown.

According to Julian Evans (1the 992), the successful use of herbicides depends on

Choosing an herbicide that will effectively control the weed.

Establishing the minimum dosage rate for effective control.

Using favourable weather conditions to reduce the risk of the herbicide drifting, volatilizing, or being carried away in the rain.

Timing the application for the optimum kill of weeds.

To safeguard plantations and water, certain rules and labels apply to herbicide use, and foresters should be conversant with these rules and labels anytime herbicides are used. Forest weeds are controlled with a range of pesticides. Any product used in forestry applications must be registered for that specific purpose. Even if they include active substances that are recognized for forest use elsewhere, products without a forestry use label must not be utilized in the forest. Many chemicals were created for use in forestry that were less toxic to people and had less of an impact on the environment. In Zimbabwe, for example, round-up has been embraced for usage in forestry.

2.4 Chemical details

Table 2. 2 Triclopyr chemical details

Name of chemical	TRICLOPYR 480G/L EC
Forms:	acid & salt
Manufacturer:	CHINA JIANGSU INTERNATIONAL ECONOMIC AND TECHNICAL COOPERATION GROUP, LTD
Target Species:	, broadleaves, shrubs, and trees
Mode of Action	Inhibitor of amino acid synthesis
Primary degradation mech	Photolysis and slow microbial metabolism
Average Soil Half-life	25-141 days

2.4.1 Synopsis of the chemical triclopyr

In forests and rangeland, this herbicide is used to control woody plants, annuals, and perennial broadleaf weeds.

Figure 2. 2 Picture of Triclopyr herbicide.

Is a broad-spectrum herbicide used to control weeds such as terrestrial annual and perennial and broadleaved herbs, woody species, and riparian species? It inhibits the synthesis of branched-chain amino acids, which limits plant development. Because triclopyr is a weak acid herbicide, its chemical structure is determined by the pH of the environment, which dictates its environmental persistence and mobility. Triclopyr's adsorption capability increases below pH

5, limiting its mobility in the soil. Triclopyr becomes negatively charged above pH 5, fails to bind securely to soils, and remains accessible (for plant uptake and/or microbial degradation). Triclopyr is mostly destroyed in soils by microbial metabolism. Photolysis and other chemical reactions, on the other hand, do not significantly degrade it. In soil, triclopyr has a half-life of one to five months. Because triclopyr has a broad spectrum of effects and can persist in the environment, caution must be exercised during application to avoid unintentional contact with non-target species.

Triclopyr is a broad-spectrum herbicide that kills annual and broadleaf plants, as well as woody plants. It can be used in conjunction with roundup for overall vegetation control or in spot applications. Triclopyr is particularly effective in killing large woody species because it is slow-acting and does not quickly break down in the plant. Privet (*Ligustrum vulgare*), blackberries (Rubus spp.), field bindweed (*Convolvulus arvensis*), and downy brome (*Bromus tectorum*) are all controlled by triclopyr (American Cyanamid 1986).

It can be used as a pre-emergent herbicide, although it is most effective as a post-emergent herbicide. Plant death is usually slow (a few weeks) and is probably connected to the amount of stored amino acids accessible to the plant.

2.4.2 Glyphosate Chemical information

The researcher employs another another chemical. Herbicide glyphosate is a kind of glyphosate. It is used to kill both broadleaf plants and grasses by spraying it on their leaves. Glyphosate in the sodium salt form is used to control plant growth and ripen specific crops.

In 1974, glyphosate was approved for usage in the United States. In the United States, glyphosate is one of the most extensively used herbicides. It's used in agriculture and forestry, on lawns and gardens, and in industrial locations to control weeds. Aquatic vegetation is controlled by some glyphosate-based products. Glyphosate is a non-selective broad-spectrum systemic herbicide. It works on grasses, sedges, broad-leaved weeds, and woody plants, among other annual and perennial plants. It can be utilized on non-cropland as well as with a wide range of crops.

Isopropyl amine salts are the most common type of glyphosate. While glyphosate is classified as an organ phosphorus molecule, it is a phosphanoglycine, not an organophosphate ester, and it does not impede cholinesterase activity. Glyphosate is a moderately hazardous pesticide with the word WARNING prominently displayed on the label. Despite the fact that the compound's LD50 values indicate that it is rather non-toxic, it can cause substantial eye discomfort. The technical product (glyphosate) and the designed product (Roundup) are essentially identical in terms of toxicity. In the rat, the acute oral LD50 is 5,600 mg/kg. Other glyphosate oral LD50 values Stevens, 199 teal The acute toxicity of glyphosate has been thoroughly studied. Extreme exposures are fairly common, and they frequently occur as a result of handling accidents. GI impairment is the most common symptom related with unintentional exposures (Roberts et al., 2010). Increased age and high plasma glyphosate concentrations (> 734 g/mL) were strongly linked to death after accidental exposure.

For numerous reasons, glyphosate is the most extensively utilized post-emergence herbicide in landscape plantings.

It is, first and foremost, effective. Glyphosate is a systemic herbicide that spreads from the treated foliage to other sections of the plant, including the roots. Glyphosate kills both annual and perennial weeds in this way. Glyphosate is not a selective herbicide. This means that most weeds grasses, sedges, and broadleaves may be controlled with one herbicide.

Glyphosate leaves little or no behind in the soil. Clay particles in the soil quickly bind to it, rendering it inert. This implies you can spray weeds beneath shrubs and trees without harming desirable plants, as long as the spray stays on the weeds and not the shrubs.

Figure 2. 3 Picture of Glyphosate/ roundup

Glyphosate is a low-cost herbicide when compared to other herbicides. It's also one of the least hazardous and environmentally friendly herbicides on the market. However, glyphosate's toxicity and environmental safety have recently been called into question. Even though the US Environmental Protection Agency maintains that glyphosate poses no risk to human health or the environment when used as directed, many agencies and individuals would prefer a different option. Many people are wondering, "What can I use instead of glyphosate?" The answer to this query will be determined by the weeds you're attempting to eradicate. Other pesticides and herbicidal-active natural items, as well as a hoe or other instrument, can easily control seedling annual broadleaf weeds. Annual weeds are more difficult to control than perennial weeds, while grasses are more difficult to control than perennial weeds. The cost of removal will be higher than with glyphosate, regardless of the method or product used. Higher chemical costs, more applications, or greater labour expenses will all contribute to this.

2.5 Tandaai Forest Natural Register

Table 2. 3 Showing a list of grass found in the Tandaai forest

Common name	Shona name	Scientific name	Location
Viscid love grass	Chidyachehuku	*Eragrostis spp*	All blocks
Finger grass	Bingambizi	*Digitaria spp*	All blocks
Thatching grass	Zhengezhu	*Hyparrhenia spp*	All blocks
Three own	Tsvairo	*Aristida spp*	D2 ,26
Dropseed	Tsinde	*Sporobolus spp*	All blocks
Okra/lady’s	Zumbai/mushani mukuru	*Abelmoschus esculentus*	All blocks

Table 2. 4 Showing Tandaai forest Shrubs

Common name	Shona name	Scientific name	Location
Wild clustered apple	Muroro	*Annona spp*	All blocks
River indigp	Rurovashuro	*Indigofera spp*	All blocks
Bee bush	Mupesepese	*Vernonathura polyanthes*	All blocks

Table 2. 5 Showing Tandaai forest Flora

Common name	Shona name	Scientific name	Location
Monkey bread	Musekesa	*Adansonia digitata*	B15
water berry	Mukute	*Syzygium cordatum*	All blocks
Chocolate berry	Mutsvubvu	*Vitex payos*	E42
African wattle	Muzeze	*Peltophorum africanum*	E 40
Simple spined num-num	Muzambara	*Carissa edulis*	E 42, 45
Snot apple	Mutohwe	*Thespesia garckeana*	B15
Wild loquat	Muzhanje	*Uapaca kirkiana*	A block
Mnondo	Munhondo	*Julbernardia globiflora*	All blocks

CHAPTER 3: METHODOLOGY

3.1 DESCRIPTION OF THE STUDY AREA

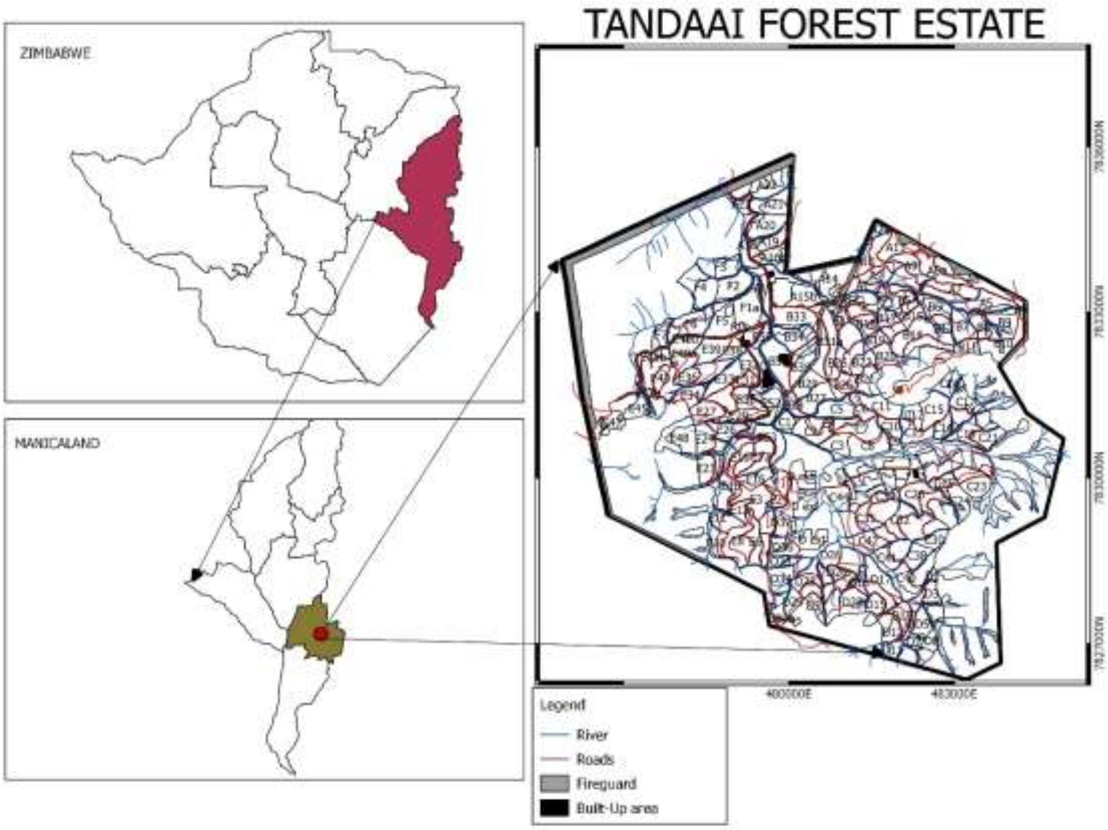

Figure 3. 1 a map depicting the study's location

3.2 study site

Tandaai woodland is part of the Allied Timbers Cashel Estate in Chimanimani district, around 104km south of Mutare and 21km east of Nhedziwa commercial area in Manicaland province. It is approximately 8km south of the Cashel offices. Mudima woodland is to the north, Ifloma estates Mozambique is to the east, and Chidiriro farm is to the west.

Tandaai estate is located between latitudes 190 271 and 190 351 and longitudes 320 48E and 320 51E and is administered by Chimanimani District Ward 1 under the traditional leadership of Chief Mutambara.

Tandaai River is a major river.

Tributaries

(i)Nyamatamba River (A & B Blocks)

(ii) Chipudzi River (C Block)

(iii) Chibudzi River (D Block)

(iv) Muzuzunge River (E block)

3.3 Geology and soils of Tandaai forest

The Umkondo system of argillaceous and quartzite series dominates the geology. Massive dark grey fine-grained crystalline quartzite sandstone with secondary shale bands intermittently capped by medium coarse-grain dined quartzite sandstones make up the upper elevation of the Tandaai river.

The soils derived from argillaceous rocks and shale consists of brown clay loams that are moderately shallow to moderately deep with a high content of clay. These may be underlain by red yellowish silt-rich clay loams. The soils derived from sandstone and quartzite are brown and fine to medium textured.

3.4 Climate

3.4.1 Hydrology

Small streams go down the slopes from all blocks and into the Tandaai River, which runs from the east through the D block area to the west and into the Mudima Umvumvumvu river.

3.4.2 Rainfall

The average yearly rainfall has been calculated to be 1150mm. The upper elevations receive up to 1800mm of rain every year. Although minor drizzles or light showers can occur at any time of year, the most of the rainfall occurs between November and March.

3.4.3 Temperature

The average annual mean temperature is 180 degrees Fahrenheit, with average maximum and lowest temperatures of 25 degrees Fahrenheit. Temperatures are cooler at higher elevations. Low-lying places like the Tandaai River have a lot of frost.

Table 3. 1 Tools and materials used

Tool	Use
Cane Knives.	-For weed slashing
Knapsack sprayer	-For applying chemical
Protective clothing (gloves, helmet, gumboots, and overalls)	-For the safety of chemicals applicators
triclopyr and glyphosate	-Chemicals used for weed control
Clipboard, exercise book, and pen	-For recordings data
Smart phone	-Taking photographs
Estate Map	-For plots layout
Personal Laptop	-for storing data

3.5 Research design

Randomised experimental design was the most appropriate method to be used for data collection using sample plots.

3.5.1 Experimental design and field layout

Square sample plot of (30m by 30m) was methodically selected and the plot boundaries were marked with stones as pegs. The researcher then produced six (6m x 6m) square plots at random inside the larger square in the compartment, demarcated them, and labelled them. Plot A1, A2, B2, B1, C1, and C2. This was for easy identification; stems were labelled in various places. Plots A1 and A2, which were sprayed with glyphosate in solution with water as per manufacturer recommendation, were employed as control plots. Plots C1 and C2 received only triclopyr treatment, while plots B1 and B2 received a combination of triclopyr and glyphosate treatment.

For the sample plots, the researcher chose one harvested pine compartment that is E16.Space between plots was 2m meters apart so that we have the same site factors, for mobility reasons and above all to avoid chemical drifting aspect. The plots were laid down at equidistance and parallel to each other.

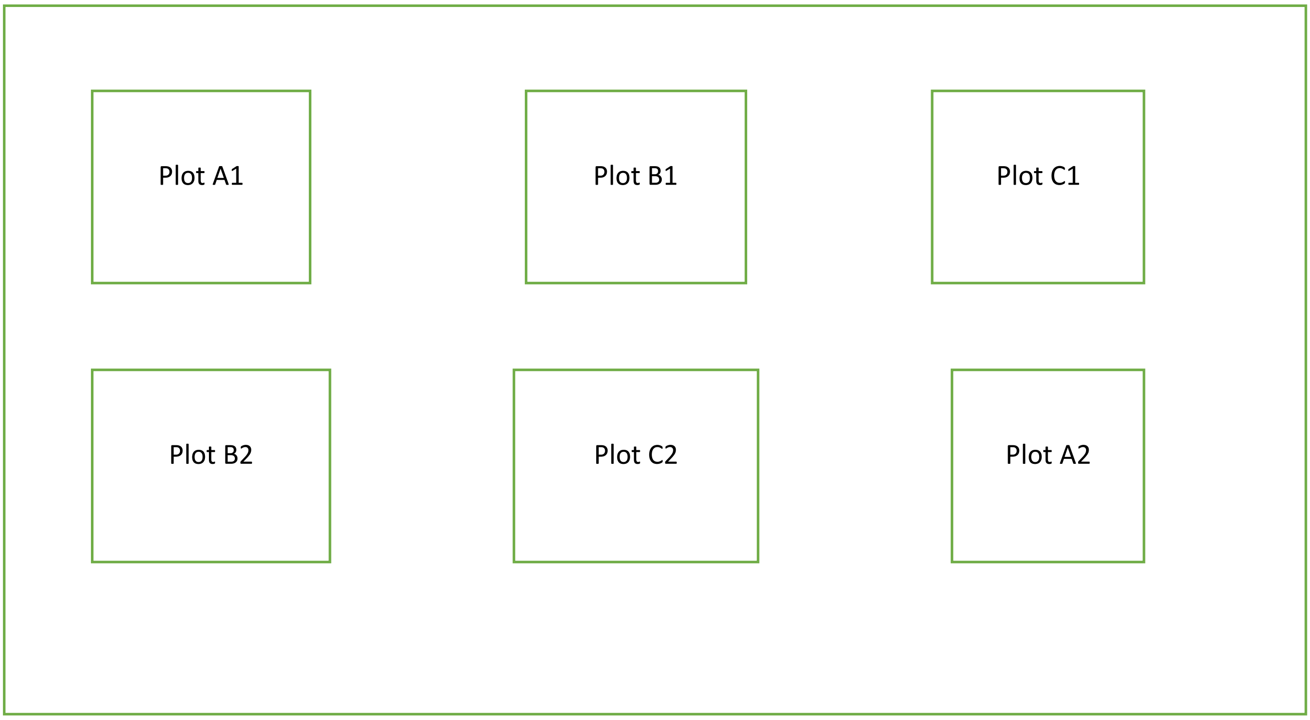

Figure 3.2 plot layout

The mixtures were as follows -

Treatment No.1 (glyphosate only)

Glyphosate (200mL) per knapsack = 16L water

Treatment No. 2 (mixture)

Triclopyr (200ml) knapsack + glyphosate(200ml)

Treatment No.3 (triclopyr alone)

Triclopyr (200ml)

After setting 30m*30m plot, the researcher measured 6 sub-plots of 6m*6m each and was set randomly within (30m*30m) plots using the zig-zag method. In that 6 square meters, all *V. polyanthese* weeds were counted and recorded. The area of 6square meters * 6 subplots gives the total area of 6square meters. The researcher calculated the plot area using the following formula:

area = length (30m) * width(30m)

This means that the total area of each plot sprayed with the chemical was 900square meters. After counting all weeds in every 1 square meter sub-plot the researcher then calculated an average number of weeds per plot using the following formula:

$$\text{The average number of weeds per 1m squared} = \frac{\text{Total number of weeds counted (6 sub-plots)}}{\text{Total number of plots}}$$

After that the researcher calculated total number of weeds per 30m*30m plots using the following formula:

The average number of weeds per 1m2 * number of 1m2 plots in 30m*30m

The researcher counted the quantity of live, regenerating, and dead *V. polyanthese* weeds after weekly chemical administration and recorded the data in a data collection form as shown in appendixes.

The following formula was used to calculate the percentage of weed killed by each chemical:

$$\frac{\text{Each chemical's total number of weeds killed Per plot}}{\text{The total number of weeds per plot}}$$

The researcher analysed all expenses, including labour, tools and equipment, and chemical costs, among other things, while estimating the cost of operation for each chemical. Following the determination of the cost of operation for each chemical, a cost-effective analysis was performed, which compared the relative cost and outcome of several courses of action. The formula was as follows:

$$\text{Cost-effectiveness:} \quad \frac{\text{Total operation costs}}{\text{Percentage achieved in controlling the weed}}$$

Because it was a common measure in forest area, the cost of operation was calculated per hectare.

3.6 Methods of data collection

3.6.1 Direct observations

This method was the major and effective method used during the study. It involves direct and complete surveillance of all plots once per week from the date of chemical application. During the observations, signals such as darkening of leaves, staining of bark, leaves displaying signs of recovery and leaves not responding to chemical and rejuvenating plants were noted and documented.

3.6.2 Inventory

Inventories is another method and technique used. This method of data collection and technique was done concurrently with direct observations. The researcher was targeting on the number of stems that shows signs rejuvenation and those not responded to the chemical at all. The information obtained using this technique was recorded.

3.6.3 Qualitative approach

The researcher took images for references as shown in appendixes during the field visit, which was a direct observation session. The researcher examined the efficacy of each chemical in terms of discoloration rate, rejuvenation rate, and all other foliage attributes based on the images.

3.6.4 Methods of and Data Analysis

Tables and graphs were the major methods to use to present all numerical and quantitative data. Data was divided into two categories during the presentation: quantitative data from inventories and qualitative data from firsthand observations and photographs. Qualitative data was represented by an image and a series of continuous statements.

The researcher evaluated the time taken to absolutely kill the weed in each plot

The cost of each chemical was calculated by comparing the quantity of chemical used each plot to the price at which it was purchased.

The researcher determines the survival rate of *Vernonanthura* stumps by physical counting live stumps over the total number of stumps in the sample plot. Coppicing failure shows the dying signs of the *Vernonanthura* stumps.

The researcher visited the plots once per week to check if the weeds had signs of toxicity. The researcher followed the same procedure of counting the stems killed and those that are surviving.

CHAPTER FOUR: RESULTS

4.1 Time taken by each chemical to kill the weed

The researcher was visiting the study area once per week after the chemical application. The below tables show the results obtained on the time taken by each chemical to kill the weed.

Table 4. 1 Showing the results on the time taken by triclopyr to kill *V. polyanthese* weed

Time	**Week1**	**Week 2**	**Week 3**	**Week4**
Alive stems	300	448	535	535
Rejuvenating stems		148	235	Nil
Dead stems	2435	2287	2200	2200

Table 4. 2 Showing the results of the time taken by roundup to kill *V.polyanthese* weed

Time	Week1	Week 2	Week 3	Week 4
Alive stems	509	519	1019	1273
Rejuvenating stems		81	510	764
Dead stems	2225	2144	1715	1461

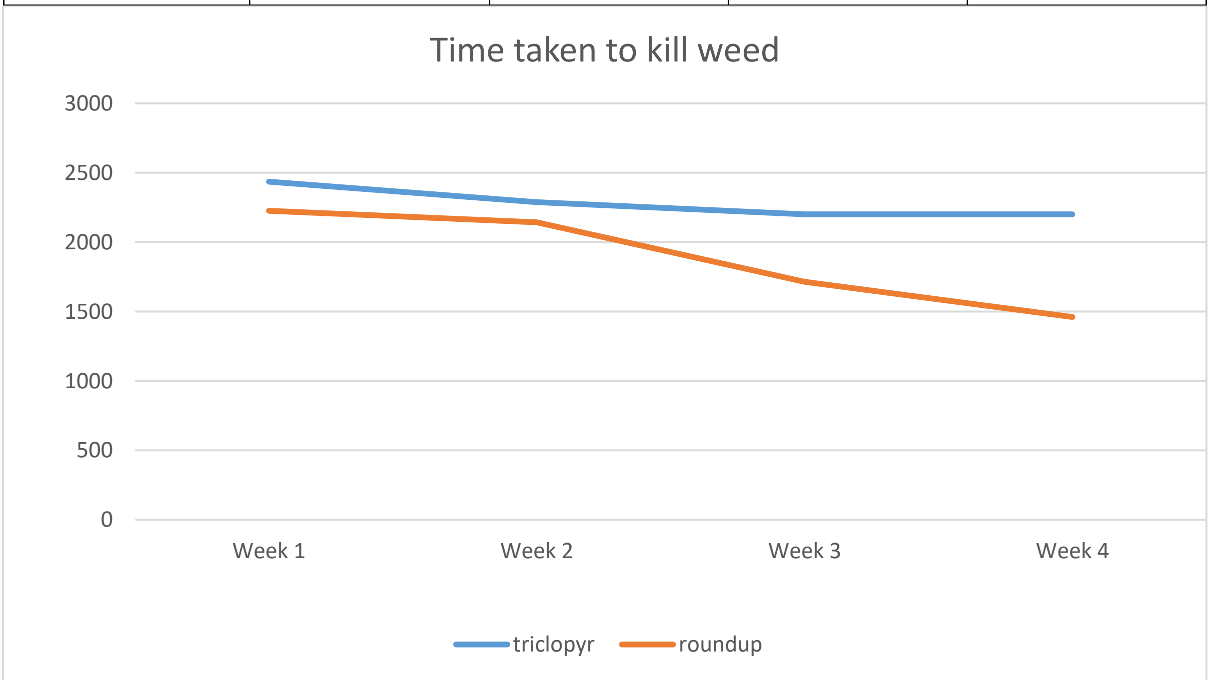

Figure 3. 3 Graph depicting the length of time it takes to destroy weed as a function of the number of stems.

4.2 Cost-effectiveness of using each chemical

The cost each operation varies depending on the chemicals utilized. Because the hectare is the most common measure used in calculating forestry area, the cost of operating was calculated per hectare. The outcomes are listed below:

Table 4. 3 Showing the cost of operation.

Chemical	Labour cost	Cost per 30m*30m plot (900 square meters)	Cost per ha
Triclopyr	US$2.3	US$7.0	US$80.0
Roundup	US$2.3	US$ 3.4	US$40.04

After determining the cost per hectare, the researcher also calculated the cost-effectiveness of each chemical per hectare using the total cost and percentage achieved on killing the weed and obtained the following results.

Triclopyr : US$80.0/89 = 0.90

roundup : US$40.04/81 = 0.50

4.3 Percentage of the weed killed by each chemical

Two chemicals under the study kill *V. polyanthese* at different times, rates, and percentages as well. The below tables show percentages killed by each chemical.

Table 4. 4 Shows the percentage killed by triclopyr chemicals.

Time	Week 1	Week 2	Week 3	Week 4
Dead stems	2435	2287	2200	2200
Live stems	300	448	535	535
Total stems	2735	2735	2735	2735
% Killed	89%	83%	80%	80%

Table 4. 5 Shows the percentage killed by roundup chemicals.

Time	Week1	Week 2	Week 3	Week 4
Dead stems	2225	2144	1715	1461
Live stems	509	591	1019	1273
Total stems	2735	2735	2735	2735
%Killed	81%	78%	64%	53%

The percentage killed by each chemical varies from the first week. Below is the graph showing percentage killed by each chemical.

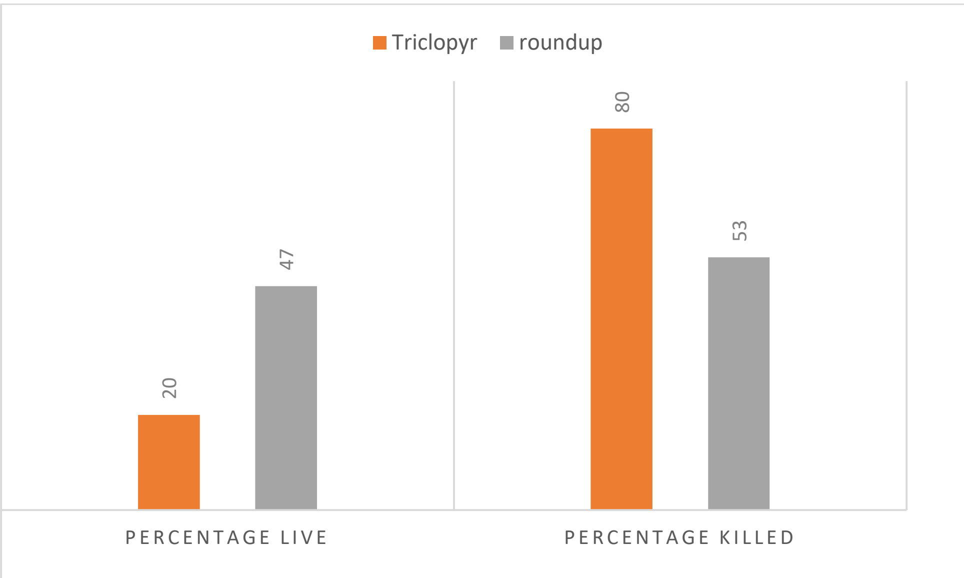

Figure 4. 1 Graph showing percentage killed by triclopyr and roundup.

CHAPTER 5: DISCUSSION

5.1 Time taken by each chemical to kill the weed

As indicated in the table and in the preceding chapter, triclopyr is more effective than roundup. In the first week, 300 *V. polyanthese* stems were alive on the triclopyr-sprayed plot and 509 stems were alive on the roundup-sprayed plot. In week three following chemical application, 535 stems in the triclopyr plot were alive, compared to 1019 stems in the roundup plot, a difference of 484 stems. As the researcher went to week four, the number of living stems in the region sprayed with triclopyr chemical remained at 535, whereas the number of live stems in the roundup plot climbed by 254 stems, increasing from 1019 stems in week 3 to 1273 stems in week 4. This means that in week three triclopyr chemical was already fully utilized and controlled the weed whereas for roundup plot the weed continues to rejuvenate.

The variation in the time of killing the weed was affected by the spraying chemical type. On the first week, 300 stems showed signs that they were still alive in the triclopyr plot and 509 on roundup plot. This clearly shows chemical was not evenly applied on both plots. The diameters of the weeds had an impact on the time it took each chemical to destroy them. Large stem diameters, especially those of 15mm and above, were resistant to the chemical. On weed diameters, triclopyr performed better. In the triclopyr experiment, weeds larger than 20mm were destroyed by the chemical, but there was some resistance, whereas in the roundup plot, most weeds larger than 15mm diameter resisted, though some were killed.

According to Hartzler (2018), roundup is a weak acid herbicide that takes a long time to break down in the plant. This means the pesticide will take longer to kill the weed, and improper application will reduce the proportion destroyed. Because the efficiency of these chemicals is controlled by their persistence and mobility in the environment, proper chemical application time is required to achieve better effects (Hartzler, 2018).

5.2 To determine the cost of operation using each chemical

From the data obtained in the previous chapter triclopyr chemical cost USD$80.0 per hectare and roundup cost USD$40.04 per hectare. This means that triclopyr cost more by USD$39.96. For further analysis, the researcher also calculated cost-effectiveness of each operation that is the degree of productivity in terms of its cost. triclopyr attained US$7.0 whilst roundup attained US$3.4. This clearly shows that triclopyr is more effective than a roundup. In terms of cost, triclopyr was more expensive by USD$39.96 but it attained more percentage in killing the weed, therefore, its effective to use as compared to roundup. Moreso, less triclopyr chemical can be mixed with water than roundup chemical.

5.3 To determine the percentage killed by each chemical

Fourth week, triclopyr sprayed plot attained 80% on weed control whereas roundup attained 53%. This means that triclopyr is more effective than a roundup. Large diameter weeds resisted more on roundup compartment hence reduced the killing percentage. Roundup is a weak acid herbicide; thus, it cannot be absorbed more effectively through plant tissue or roots than triclopyr chemical. Roundup absorption to soil particles is generally weak, according to Hartzler (2018), but it varies depending on the soil particle. This means that, roots cannot easily absorb the chemical hence it affects the killing percentage.

In comparison to roundup, a slow-acting and weak acid herbicide, triclopyr is a fast-acting herbicide that may be easily and quickly digested in plants (Hartzler, 2018). It generated a higher killing percentage. Because chemicals stay in the environment, it is recommended to apply roundup directly to vegetation using a low volume backpack, cut stump, or basal bark application rather than utilizing a broadcast spray approach (Miller, 1967). This also affected the percentage of weeds killed by roundup chemicals. The above equipment needed was expensive for the researcher therefore ordinary knapsack sprayer was used and was also one of the contributing factors that affected the percentage.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Using a case study of Allied Timbers Pvt Limited, Tandaai estate under the jurisdiction of Chimanimani district council, this study was designed to evaluate the efficacy of two herbicides (TRICLOPYR 480 EC and glyphosate/roundup) for the eradication of *Vernonanthura polyanthese* weed in forest plantations. According to the research findings collected throughout the trial, TRICLOPYR 480 EC is more successful than roundup, with a percentage killed of 80 percent and 53 percent, respectively. The active ingredient in triclopyr chemicals is triclopyr, which is easily absorbed by plant tissues and thus more effective. Roundup, on the other hand, has the chemical isopropyl amine, a weak acid herbicide that takes time to kill the weed and hence allows for the renewal of treated plants. Triclopyr had an 80 percent weed control and suppression rate on the fourth week, while roundup had a 53 percent weed control and suppression rate, which is 27 percent less. Roundup was less expensive to operate by USD$39,96 per hectare, however the data reveal that it is less successful. Triclopyr chemical appears to give good control of broadleaf weeds in a nut shale, even at rates comparable to roundup.

6.2 Recommendations

Using the research findings obtained during the study, it is recommended that:

Using TRICLOPYR 480 EC is more effective than a roundup.

Concentrated roundup has a low acute toxicity when applied to the skin or consumed, but it is dangerous when inhaled and can cause irreversible damage. As a result, applicators are advised to wear chemical-resistant protective clothes, including respirators.

Integrated weed control, which is a mixture or sequential usage of numerous treatments, such as burning, slashing, or cutting back followed by chemical application, is frequently required for successful weed management.

To lower the cost per hector, slash the weed, allow it to dry, and then burn it before applying the chemical. This is because *Vernonanthura polythese* sprouts after any disturbance, so the stems will be small and it will be easier for the chemical to work properly as compared to larger items, as well as reducing the amount of chemical to be sprayed, which was observed by the researcher that the density of the weed was too high and even the rate of spraying was too low due to the state of the density of the weed, but after burning and it sprouts, it may be easy even to work.

Furthermore, the researcher suggested that more research be done on methods that can totally kill the weed, as this method only worked on live weeds, and after their death from the administration of triclopyr from the roots near to the plant station, another weed grows.

Last but not least, perform triclopyr chemical follow-ups to ensure that the weed is eradicated until the canopy of timber species in a plantation area is closed, preventing underground plants from growing in an established plantation.

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Appendices 1

Data Collection Form

Estate:

…………………………………………………………………………………………………… ……………………………………………

Compartment: ………………………………………… Plot Number……………………………………………….

Date assessed: ………………………………………… Assessed by………………………………………………….

Plot Number/Name	**Live stems**	**Dead stems**	**Total count**

Appendices 2

The table below was used by the researcher to calculate the cost of the operations

	Cost per Trial ($)	
	Unit cost ($)	Total cost ($)
glyphosate spray (200ml)		
Labour cost (2units/ha		
Total		
triclopyr mixed(200ml) with water and glyphosate (200ml)		
Labour cost (2units/ha)		
Total		
triclopyr (200ml)		
Labour		
Total		

Appendices 3 Gallery