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TITLE: ASSESSMENT OF ANTHELMINTIC ACTIVITY OF *Erythrina abyssinica* (MUTITI TREE) AND *Cissus quadrangularis* (MURUNJURUNJU TREE) DRIED COMPONENTS AGAINST GASTROINTESTINAL PARASITES IN GOATS.

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APPROVAL PAGE

The signatories confirm that they have read and recommended to the Bindura University of Science Education for acceptance of the project title:

ASSESSMENT OF ANTHELMINTIC ACTIVITY OF *Erythrina abyssinica* (MUTITI TREE) AND *Cissus quadrangularis* (MURUNJURUNJU TREE) DRIED COMPONENTS AGAINST GASTROINTESTINAL PARASITES IN GOATS.

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ABSTRACT

Gastrointestinal nematodes remain one of the biggest problems facing goat farmers in Zimbabwe. The situation is made worse by growing resistance to commercial de-wormers, and by the fact that many rural households simply cannot afford or access veterinary products regularly. This study set out to test, under real field conditions, whether dried aqueous preparations of *Erythrina abyssinica* (mutiti tree) and *Cissus quadrangularis* (murunjurunju tree) could meaningfully reduce worm burdens in naturally infected communal goats in Ward 5, Crown Range, Chiredzi District.

Thirty-two goats were randomly split into eight treatment groups of four animals each, following a 2x3 factorial design. Three dosage levels were tested for each plant species: 15 g/L (low), 30 g/L (medium), and 50 g/L (high). A group receiving water only served as the negative control, while a group dosed with Valbazen served as the positive control. All preparations were given orally at 5 mL/kg over two consecutive days. The faecal samples were collected before treatment (Day 0) and again on Days 7, 14, and 21. Efficacy was measured using Faecal Egg Count Reduction percentage (FECR%) and the Henderson-Tilton (HT) formula, and the results were analysed with two-way ANOVA.

Both plant preparations reduced worm egg output in a dose-dependent fashion at every concentration tested. At 50 g/L, *Cissus quadrangularis* hit a Day 14 FECR% of 72.8% and a Day 21 HT efficacy of 69.7%, which comes very close to the 70% threshold WAAVP (2004) defines as meaningful anthelmintic activity. *Erythrina abyssinica* at the same concentration reached 65.9% FECR% and 65.6% HT efficacy at Day 21. Two-way ANOVA confirmed highly significant main effects for both dosage level (Day 14: $F(2,18) = 755.05$, $p < 0.001$) and plant species (Day 14: $F(1,18) = 133.74$, $p < 0.001$). The interaction term between species and dosage was not significant at any time point ($p > 0.05$). Not a single animal showed any adverse reaction across the full 21-day trial. Both null hypotheses (H01 and H02) were rejected.

The results show that both plants are safe, reasonably effective, and could realistically be used as low-cost deworming options in smallholder goat production. Based on the findings, *Cissus quadrangularis* at 50 g/L, dosed every two weeks, is recommended as the primary

botanical preparation for communal goat parasite management in Ward 5 and similar settings.

DEDICATION

This dissertation is dedicated to my family, who stood by me throughout every difficult moment of this journey their encouragement and patience made it possible to see it through. It is also dedicated to the goat keeping households of Ward 5, Crown Range, who opened their homes, their land, and their livestock to this research without hesitation

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To the households of Village 2, Ward 5, Crown Range, Chiredzi District - I am truly grateful. You trusted this process and gave freely of your time, your animals, and your land. The Chiredzi District Veterinary Department also deserves recognition for their practical assistance and for helping with data logistics. I am also grateful to my fellow students, parents and colleagues for their intellectual companionship and moral support throughout the research process. Finally, I thank God for the strength, health, and determination to complete this work.

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CHAPTER ONE (1)

1.1 INTRODUCTION

Gastrointestinal parasitism represents a significant global challenge for the goat farming industry, causing substantial morbidity, mortality and economic losses through reduced productivity and increased veterinary care costs (Charter and Paraud, 2012; Palomino-Guerrera *et al*., 2024). These parasites, particularly gastrointestinal nematodes (GIN), have a multifaceted impact on goat production, affecting wool and milk quality, skeletal growth, and live-weight gain (Fernandes *et al*., 2025; Cai *et al.*, 2023). Control of gastrointestinal parasites has traditionally relied heavily on the use of chemical anthelmintics (Rahmann and Seip, 2007; Caram *et al*., 2025). However, this approach is becoming increasingly unsustainable due to the rapid development of anthelmintic resistance among parasite populations (Atanasio-Nhancumbe *et al*., 2019; Mihalca *et al*., 2024). The emergence of resistance not only compromises the effectiveness of valuable treatments but also underscores the urgent need for alternative control strategies that are both effective and sustainable (Levecke *et al*., 2021; Kaminsky *et al*., 2020).

In recent years, researchers and farmers alike have started paying serious attention to plants as potential alternatives to synthetic dewormers (Mhlongo et al., 2024; Caram et al., 2025). Traditional medicine has long utilized various plants for their medicine properties, including their anthelmintic activity (Andrade-Montemayor *et al*., 2019; Villarn *et al*., 2024). The use of plant-based remedies offers several advantages including reduced environmental impact, lower risk of residue in animal products and the potential to slow the development of resistance (Ramdani *et al*., 2023; Melo *et al*., 2020). Plant based bioactive compounds such as terpenes (essential oils) and other secondary metabolites including tannins and alkaloids have been proposed as natural anthelmintics with promising efficiency (Caram *et al*., 2025; Mhlongo., 2024).

Erythrina Abyssinia (Mutiti tree) and Cissus quadrangularis (Murunjurunju tree) are two plants with established use in traditional medicine in various African regions (Obakiro *et al*., 2021; Zenebe *et al*., 2017*). E. abyssinia* is known for its diverse medicinal properties, including anti-inflammatory, antibacterial, antioxidant and ant plasmodial activities, with

traditional use as an anthelmintic for various livestock ailments (Obakiro *et al*., 2021; Agaba *et al*., 2013).

C. quadrangulas has been traditionally used by pastoralist and agropastoral to control helminthiasis, tick and lice infestation in livestock, with recent in vitro studies demonstrating promising anthelmintic activity against *Haemonchus contortus* (Zenebe *et al.*, 2017; Makhafola *et al*., 2021). Despite their traditional use and preliminary laboratory evidence, the in vivo anthelmintic activity of these plants against gastrointestinal parasites in goats requires further scientific validation under filed conditions.

This study aims to investigate the anthelmintic activity of dried components from *Erythina abyssinica* and *Cissus quadrangularis* against gastrointestinal parasites in goats. By evaluating the anthelmintic activity of these plant dried components, this research seeks to contribute to the development of natural and sustainable alternatives to chemical anthelmintics. If these plants can be shown to work, they offer a deworming option that farmers can prepare themselves from trees already growing in the area, with no specialist equipment and at virtually no cost.

1.2 BACKGROUND OF STUDY

Goats are central to the livelihoods of many smallholder families across Zimbabwe, particularly in the semi-arid communal areas of the south. They are sold when cash is needed, consumed as a source of protein at household level, and exchanged as assets in local trade systems (Zvinorova *et al.*, 2017). Yet their productivity is held back, year after year, by gastrointestinal nematodes. The species causing the most damage in small ruminants are *Haemonchus contortus*, *Trichostrongylus* spp., and *Strongyloides* spp. worms that cause anaemia, weight loss, reduced fertility, and, in bad cases, death.

Most farmers who treat for worms use broad-spectrum de-wormers such as albendazole or ivermectin, either as a preventive measure or in response to visible illness (Rose Vineer *et al*., 2020). The problem is that using the same chemicals repeatedly often at estimated rather than weight-based doses, creates ideal conditions for resistance to develop. Parasites that survive treatment pass on their resistance traits, and over time the whole parasite population shifts toward being drug-resistant (Kaplan, 2004; Kotze and Prichard, 2016). Studies confirming this pattern have been published from across sub-Saharan Africa and elsewhere

(Rodrigues et al., 2025). In rural communal settings, the situation is made even harder by the cost of commercial products and their irregular availability at local agrovets. Many families dose their animals infrequently or not at all simply because they cannot afford to do otherwise (Rahate *et al*., 2024). These challenges highlight why more research is needed into natural alternatives (Mazhangara *et al*.,2020; Fankam & Kuete ,2024) specifically focusing on plants' traditional uses backed up by modern science looking into new ways we could combat these stubborn worms without breaking budgets (Venkataraman *et al*.,2025; Obakiro *et al*.,2021).Helminthic infections present a major challenge to livestock productivity across the globe, with gastrointestinal parasites causing the majority of damage in species such as cattle, goats, and sheep. The cost of controlling parasites takes a toll on livestock owners, particularly in rural communal farms. In developing countries, such as South Africa, commercial drugs are expensive and sometimes unavailable, leading to the use of poor quality or altered products. Most farmers (89%) rely solely on anthelmintics drugs (Emsley *et al.*, 2023). Farmers use visual appraisal to estimate the dosage, which is the primary cause of resistance (Emsley *et al*., 2023). For example, the *Haemonchus contortus*, a gastro-intestinal parasite of sheep, has shown a remarkable propensity to develop resistance to all the drugs used in its control (Gilleard, 2013, advances in Parasitology, 83, 237-293). Even small residue levels pose public health risks, including antimicrobial resistance, allergic reactions, and genetic toxicity. When farmers treat animals without proper guidance, misuse the drugs and increase the risk of drug residues entering the food chain (Ture *et al.*, 2019).

Synthetic antihelmintics create health risk concerns among livestock and consumers, with one of the primary considerations being the residues left by chemical (Ozaraga *et al.*, 2024). *Erythrina abyssinica*, locally known as Mutiti, is a deciduous tree traditionally used in East and Southern Africa for treating various ailments in both humans and animals. Different extracts and phytochemicals from parts of *E. abyssinica* have been scientifically proven to possess anti-inflammatory, antibacterial, antioxidant, ant plasmodial, antiproliferative, antifungal, antimycobacterial, antidiarrheal, anti-HIV 1, antidiabetic, and ant obesity activities (Obakiro *et al.*, 2021). *Erythrina abyssinica* has been of great use by farmer in Kenya to control worms in local chicken *(Lagu & Kayanja, 2013*. Several sources confirm that *Erythrina abyssinica* extracts have shown anthelmintic activity in in vitro studies, with

efficacy comparable to synthetic drugs like piperazine citrate, particularly against nematodes such as *Ascaridia galli* (Lagu and Kayanja, 2013; Obakiro *et al*., 2021).

Figure 1.2.1 Shows images of the *Erythrina abyssinica*



Cissus quadrangularis, locally known as "murunjurunju" in Zimbabwe, is a traditional herbal medicine used for a variety of purposes, including bone health, joint pain, metabolic and digestive concerns, and as a wound remedy (Stohs and Ray, 2013; Flora of Zimbabwe, 2025). Studies support the plant's anti-inflammatory and protective effects, which are linked to its antioxidant properties and flavonoid content (Prabhavathi *et al.*, 2017). The plant has shown some anthelmintic potential in the in vitro studies using methanolic extracts against specific parasites (Chinyoka *et al*., 2021). A separate in vitro study, using extracts from the aerial parts of the plant, demonstrated dose-dependent adulticidal and egg-hatching inhibitory effects against the barber pole worm, *Haemonchus contortus*, with high efficacy comparable to standard drugs (Zenebe *et al*., 2017).

Figure 1.2.2 Shows 2 images of the *Cissus quadrangularis*



While synthetic anthelmintic drugs have long been the foundation of parasite control in livestock, escalating challenges such as drug resistance, high costs, and residue-related health risks underscore the urgency of exploring safer, more sustainable alternatives (Kaplan, 2004; Toma *et al.*, 2024; Ture *et al*., 2019). *Erythrina abyssinica* is traditionally valued across East and Southern Africa, exhibits a compelling pharmacological profile with both direct anthelmintic potential and indirect nutritional benefits (Obakiro *et al*., 2021). While prior studies have demonstrated efficacy in vitro and against other parasite species like *Ascaridia galli*, further field investigations are essential to validate its application in goat-specific gastrointestinal parasite control (Lagu and Kayanja, 2013; Obakiro *et al*., 2021. This study will assess the antihelmintic potential of *E. abyssinica* and Cissus quadrangularis dried components against gastrointestinal parasites in goats, contributing to integrated parasite management strategies that are locally relevant, economically viable, and aligned with public health priorities.

1.3 STATEMENT OF THE PROBLEM

Goat farmers in Crown Range, Ward 5, are losing animals and income to gastrointestinal nematode infections at a rate that existing control methods cannot adequately address. Communal grazing, which is the norm in this area, means that animals from many different households share the same pastures, keeping larval contamination levels high year-round and making individual parasite management extremely difficult (Zvinorova *et al.*, 2017; Mazhangara *et al*., 2020).

Commercial anthelmintics albendazole, levamisole, and the macrocyclic lactones - were once highly effective and formed the backbone of parasite control programmes across Zimbabwe. That is no longer reliably the case. Reports from field veterinarians working in Masvingo and Mashonaland Central have documented cases where post-treatment faecal egg counts did not fall as expected, pointing to resistance in local *Haemonchus* populations (Zimbabwe Veterinary Association, 2018). This is supported by the work of Mushonga *et al*. (2024), who recorded resistance to ivermectin, albendazole, and levamisole in sheep populations in Mashonaland Central, and by Mapfumo and Chimonyo (2011) and Mpofu *et al*. (2022), who reported persistent parasite burdens in communally kept small ruminants despite regular chemical treatment.

There is also the question of cost and access. Even when a drug still works, many families in Ward 5 cannot access or afford it consistently enough to maintain adequate parasite suppression. This means the practical gap between what the drugs can theoretically do and what actually happens at farm level is often very wide.

Despite the long history of traditional plant use in this region, and despite preliminary laboratory evidence that both *E. abyssinica* and *C. quadrangularis* have genuine antiparasitic properties, no properly designed in vivo study has been conducted to validate these plants against GIN in goats under Zimbabwean field conditions. That gap is the core problem this research addresses.

1.4 JUSTIFICATION OF THE RESEARCH

Goats significantly contribute sustaining livelihoods particularly rural residents residing within Crown Range area. Across the six villages of Ward 5, approximately 520 households keep an average of six goats each, giving a total herd of around 3,236 animals according to Department records from July of the study year. Keeping those animals healthy is not a peripheral concern; it is central to household food security and economic stability in the area.

Gastrointestinal parasites are the single most important health constraint on goat production in this area. Infections worsen significantly during the rainy season, and the consequences - weight loss, poor reproduction, and animal deaths - fall hardest on families who are already operating on tight margins. The current reliance on synthetic de-wormers is not working well enough, for reasons already outlined: drug resistance is spreading, costs are high, and supply is unreliable.

Both the mutiti tree and the murunjurunju tree grow naturally throughout the Crown Range area. They do not require purchasing, they can be propagated from cuttings or seed without specialist knowledge, and the preparation process shade drying the plant material, grinding it, and mixing it with water requires only a mortar and pestle, which is already found in most households. If these preparations can be shown to work at a meaningful level, farmers could begin using them immediately without any new infrastructure or external input.

Integrating locally available plant knowledge with systematic scientific testing also reflects a broader commitment to making livestock health solutions relevant to the people who actually

need them. The findings of this study have the potential to feed into extension training, community deworming programmes, and policy conversations around formal recognition of validated botanical anthelmintics.

1.5 BROAD OBJECTIVE

To evaluate the antihelmintic efficacy of *Erythrina abyssinica* (mutiti tree) and *Cissus uadrangularis* (murunjurunju) dried components against gastrointestinal parasites in goats.

1.6 SPECIFIC OBJECTIVES

1. To compare reduction in faecal egg count (FEC) between goats treated (at different titrated dilutions) with *Erythrina abyssinica, Cissus quadrangularis* and those not treated.
2. To assess the efficacy of the *Erythrina abyssin*ica and *Cissus quadrangularis* dried components at different dilutions.

1.7 HYPOTHESIS

H_{01}: There is no difference in mean FEC reduction among goats treated with titrated dilutions of *Erythrina abyssinica, Cissus quadrangularis*, or an untreated control group.

H_{02}: The percentage reduction in FEC produced by dried *Erythrina abyssinica* and *Cissus quadrangularis* is the same across all tested dilutions.

CHAPTER TWO (2)

LITERATURE REVIEW

This chapter reviews relevant literature on gastrointestinal nematodiasis in small ruminants, the global crisis of anthelmintic resistance with specific reference to the Zimbabwean context, and the ethnobotanical, phytochemical, and bioactivity profiles of *Erythrina abyssinica* and *Cissus quadrangularis*. The chapter further examines extraction methods, potential synergistic interactions, and identifies the research gaps that this study seeks to address.

2.1 The Global Burden of Gastrointestinal Nematodiasis in Small Ruminants

Parasitism is a significant concern for goat farming infections can lead to health issues that hinder animal performance and cause economic setbacks (Mazhangara *et al*., 2020). These subclinical losses are often underestimated precisely because they accumulate quietly over time rather than announcing themselves with obvious clinical signs (Mavrot *et al.*, 2015; van der Voort *et al*., 2013; Fitzpatrick, 2013). In goats and sheep specifically, the strongyle nematodes dominate, and of these, *Haemonchus contortus* the barber pole worm stands out as the most dangerous species across tropical farming environments (Charlier *et al*., 2021)

At scale, this leads to severe anaemia, particularly in young animals and recently kidded does whose immune responses are already under strain (Besier *et al*., 2016; Slayi, 2023). Known colloquially as barber pole worm due to its appearance, *H. contortus* becomes particularly dangerous because its feeding habits can induce severe anemia among affected animals especially prevalent within tropical/subtropical agricultural settings where it's often blamed for parasitic gastroenteritis cases affecting livestock (Besier *et al*., 2016). An individual adult worm might consume up to .05 ml daily leading rapidly towards production dips and even deaths in younglings or mothers who have weakened immune responses after giving birth. Research has shown widespread occurrences of AHR across various helminth species against numerous classes of deworming drugs used throughout different types livestock populations too (Falzon *et.al*., 2013; Kaplan, 2020).

2.2 The Crisis of Anthelmintic Resistance

Gastrointestinal nematodes particularly *Haemonchus contortus* are major players limiting goat output across sub-Saharan Africa largely attributed rising drug resistance coupled with limited access options available commercially speaking (Charlier *et al*., 2021; Vatta and Lindberg, 2006). (Rodrigues *et al*. 2025) conducted a systematic review of molecular mechanisms underlying anthelmintic resistance in *H. contortus*, documenting that resistance has been reported to all major anthelmintic classes including benzimidazoles, macrocyclic lactones, and nicotinic agonists. A key factor driving this resistance is the inadequate awareness and misuse of anthelmintics by farmers (Mukherjee *et al*., 2023). Widespread and improper use of various anthelmintics, genetics and epidemiological factors has resulted in anthelmintic resistance in livestock (Mukherjee *et al*., 2023). Reports show that the excessive use of these drugs has caused multi-drug-resistant parasite strains, which threaten the livestock industry worldwide (Costa *et al*., 2022). Studies in both field and laboratory settings have confirmed AR in goats. A 2021 study in Romania, Transylvania on dairy goat farm confirmed anthelmintic resistance in *Haemonchus contortus* (Portaniche *et al*., 2021).

Each of these practices applies selection pressure to parasite populations in ways that favour resistant genotypes. Over time, what were minor resistant subpopulations become the majority (Kotze and Prichard, 2016). Multi-drug resistant strains have now been reported from numerous countries and represent a genuine threat to the commercial viability of small ruminant farming in some regions (Costa *et al.*, 2022).

2.2.1 Anthelmintic Resistance in Zimbabwe and Southern Africa

Closer to home, the evidence from Zimbabwe is concerning. Mushonga *et al*. (2024) carried out field trials in Mashonaland Central Province and found that faecal egg count reduction tests for ivermectin, albendazole, and levamisole all fell below the thresholds that would indicate adequate efficacy. This pattern multi-drug resistance across the three main drug classes is exactly what you would expect to find in a farming context where the same products have been used intensively for many years without proper dose calibration or strategic rotation. While the Mushonga *et al*. (2024) study was conducted in sheep rather than

goats, the implication for goat-rearing communities in Zimbabwe is clear: if resistance is established in one small ruminant species in the country, it is likely only a matter of time before the same patterns emerges in goat herds managed under similarly intensive treatment regimes.

2.3 Summary of the Anthelmintic Resistance Crisis

The picture that emerges from sections 2.1 and 2.2 is straightforward: the drugs that farmers have depended on are becoming less reliable, the cost of accessing them in rural Zimbabwe is already a barrier for many families, and the standard response of dosing more frequently or at higher rates only accelerates resistance development rather than solving the underlying problem. In settings like Ward 5, Crown Range, where communal grazing guarantees continuous reinfection from contaminated pastures, this creates an urgent need for alternatives that work, cost very little, and are available locally. Sections 2.4 and 2.5 examine whether *E. abyssinica* and *C. quadrangularis* could provide such an alternative.

2.4 *Erythrina abyssinica*: Ethnobotany, Phytochemistry and Bioactivities

Erythrina abyssinica known as mutiti in Zimbabwe, and as coral tree, lucky bean tree, or flame tree in wider use is one of the most widely recognised medicinal plants across eastern and southern Africa (Obakiro *et al*., 2021). Local Shona names include mutsavatsa and musesese. It belongs to the family Fabaceae and is broadly distributed throughout tropical and subtropical Africa. Ethnomedicinal surveys across the continent have documented its use for an impressive range of conditions, including helminthiasis in livestock (Obakiro *et al*., 2021), and a 2021 systematic review confirmed that its traditional use as an antiparasitic spans East, Central, and Southern Africa.

2.4.1 Traditional Medicinal Applications and Ethnobotanical Context

The parts of *E. abyssinica* most commonly used medicinally are the leaves, stem bark, and roots. Bark decoctions are the traditional preparation of choice for treating intestinal worms in livestock, though methods vary by region and the condition being treated (Obakiro *et al*., 2021). Aime *et al*. (2024) carried out a broad review of the genus Erythrina and found that its ethnomedicinal uses are remarkably consistent across geographically distant communities,

which they interpreted as reflecting a shared phytochemical basis rather than coincidental convergence.

2.4.2 Phytochemical Composition

The active chemistry of *E. abyssinica* centres on its alkaloids and condensed tannins, with the specific compounds present varying to some extent depending on which part of the plant is used and how it is prepared (Obakiro *et al.,* 2021). The bark, which is the plant part used in this study, contains alkaloids structurally analogous to known neuroactive compounds, as well as polyphenols that interact with parasite biochemistry through multiple pathways.

2.4.3 Mechanisms of Anthelmintic Action

Polyphenolic compounds, including the condensed tannins found in *E. abyssinica*, work against parasites partly by interfering with their energy metabolism. Tannins bind to surface proteins and digestive enzymes, disrupting nutrient uptake and weakening the integrity of the cuticle. They also chelate metal ions, stripping parasites of cofactors needed for enzyme function (Costa *et al.,* 2022). The alkaloids in this species target the nervous system of parasites, particularly acting on nicotinic and GABAergic neurotransmitter pathways. The result is neuromuscular disruption, paralysis, and eventually detachment from the gut wall and expulsion. Importantly, at therapeutic concentrations these alkaloids are considerably more toxic to parasite nervous systems than to mammalian hosts, which is what gives the preparation its useful safety profile (Obakiro *et al*., 2021).

2.4.4 In Vitro and In Vivo Anthelmintic Evidence

The laboratory evidence supporting *E. abyssinica* as an anthelmintic is reasonably solid, even if the in vivo data under field conditions remain limited. Lagu and Kayanja (2013) showed that aqueous and ethanolic bark extracts reduced *Ascaridia galli* activity in laboratory assays to a degree comparable with piperazine citrate. While *A. galli* is an avian nematode rather than a ruminant one, the results confirm that the mechanisms are real and transferable across nematode types. Kariuki *et al*. (2020) took things further with participatory field trials in Kenya, where crude bark decoctions given to naturally infected livestock produced significant reductions in parasite loads an important result because it was achieved under practical, uncontrolled farming conditions rather than in a laboratory.

2.4.5 Toxicity and Safety Considerations

The main safety concern with *E. abyssinica* is confined to the seeds, which contain alkaloids capable of causing severe neurological toxicity at relatively low doses (Obakiro *et al*., 2021). The bark and root preparations traditionally used in veterinary practice contain much lower alkaloid concentrations. When prepared by decoction rather than from seed material, the safety profile is considered acceptable.

2.5 *Cissus quadrangularis*: Ethnopharmacology and Anthelmintic Properties

Cissus quadrangularis belongs to the family Vitaceae and is a perennial succulent vine with a highly distinctive four-angled, segmented stem. It is found across tropical and subtropical Africa and Asia and is known locally in Zimbabwe as murunjurunju.

2.5.1 Traditional Veterinary Applications

Ethnobotanical surveys conducted across East and Southern Africa have recorded *C. quadrangularis* as a plant that farmers reach for when their animals have worm problems, tick infestations, or lice (Zenebe *et al.*, 2017). In Zimbabwe, local farmers in communal areas have used the plant similarly, though these practices have not been thoroughly documented in peer-reviewed scientific literature.

2.5.2 Phytochemical Composition and Bioactive Compounds

*C. quadra*ngularis has a notably diverse chemical profile. Stohs and Ray (2013) documented flavonoids, triterpenoids, alkaloids, saponins, iridoids, stilbenes, vitamins, steroids, and a group of steroidal compounds specific to the species known as quadrangularins. This breadth of phytochemical diversity is thought to be part of what makes it effective against parasites - rather than relying on a single mechanism, it hits multiple targets simultaneously.

2.5.3 Anthelmintic Activity: Experimental Evidence

The most directly relevant laboratory data come from Zenebe *et al*. (2017), who tested crude methanolic extracts from the aerial parts of C. quadrangularis against both adult worms and eggs of *Haemonchus contortus*. At a concentration of 10 mg/mL, adult worm mortality

reached 100%. At 1 mg/mL, egg hatching was inhibited by 88%. These are striking results, and they were obtained with a well-controlled experimental design. The main caveat is that methanol was used as the extraction solvent rather than water, which raises the question of whether the same efficacy would be achieved with traditional water-based preparations. This question is directly addressed by the present study.

2.5.4 Bioavailability and Practical Preparation Considerations

The effectiveness of any herbal preparation depends heavily on which compounds get extracted and at what concentration. Zenebe *et al.* (2017) noted that methanolic extraction pulls out lipophilic compounds at higher concentrations than aqueous preparations achieve. However, Stohs and Ray (2013) pointed out that the flavonoids and saponins most responsible for *C. quadrangularis* anthelmintic activity are water-soluble, meaning that traditional aqueous preparations are not as disadvantaged as one might assume. For field use, the stem segments can be shade-dried and ground to a powder that suspends readily in water a straightforward preparation that any farmer in Ward 5 could carry out without specialist knowledge or equipment.

2.5.5 Safety Profile and Toxicological Assessment

Toxicological testing of *C. quadrangularis* extracts has consistently returned reassuring results. Stohs and Ray (2013) reported LD50 values above 3000 mg/kg in animal models from acute toxicity studies, which represents a very large margin above the concentrations used therapeutically. Sub-chronic studies at 2000 mg/kg body weight showed no meaningful adverse effects on blood parameters, organ biochemistry, or tissue histology. This safety profile supports its use in veterinary applications.

2.6 Extraction Methods and Traditional Preparation Techniques

For *E. abyssinica*, the standard traditional approach involves boiling bark or root pieces in water to produce a decoction, or soaking them in cold water for an extended period before use. Some farmers also allow animals to gnaw directly on bark, or mix dried and powdered plant material into feed.

For *C. quadrangularis*, the approach is simpler given the succulence of the stems fresh stems can be mashed to release juice, or dried stem pieces can be boiled into a decoction. A key practical advantage is that the high-water content of the stems makes juice extraction easy without any equipment beyond hands or a basic press. Aqueous extracts in general are good at dissolving glycosides, tannins, saponins, and polar alkaloids, whereas organic solvents extract a broader range of lipophilic compounds (Costa *et al*., 2022). The choice of solvent therefore affects what is extracted and in what quantity.

2.7 Synergistic Interactions and Combination Therapies

The fact that many traditional anthelmintic remedies across Africa use combinations of several plant species rather than any one plant alone suggests that practitioners recognised, even without a formal pharmacological framework, that plants can work better together than individually (Rahate *et al*., 2024). There is a logical basis for this: the compounds found in different plants act through different mechanisms flavonoids create oxidative stress, terpenoids interfere with motility and egg hatching, saponins disrupt cell membranes. Using plants with different compound profiles simultaneously could attack multiple parasite targets at once, potentially improving overall efficacy and making it harder for resistance to develop to any single mechanism (Rahate *et al*., 2024).

In the case of *E. abyssinica* and *C. quadrangularis*, the theoretical basis for a synergistic combination is reasonable one plant contributes mainly alkaloids and tannins, the other brings saponins, flavonoids, and steroids. However, no study has yet tested whether these two species used together produce effects greater than either alone. This study did not investigate combination treatment, but it establishes individual efficacy baselines that would be a prerequisite for any future synergy testing.

2.8 Research Gap and Study Justification

The literature leaves a clear gap. Zenebe *et al.* (2017) generated useful quantitative data on *C. quadrangularis* against *H. contortus*, but used methanolic rather than traditional aqueous extracts. *E. abyssinica* has solid ethnobotanical documentation and some in vitro and participatory trial evidence, but specific in vivo efficacy data against ruminant gastrointestinal nematodes using water-based preparations is absent from the peer-reviewed

literature. Neither species has been tested in vivo under Zimbabwean communal farming conditions. And the worsening resistance picture documented by Mushonga *et al*. (2024) and others makes finding workable alternatives more urgent, not less.

This study was designed to fill that gap directly by conducting a properly controlled in vivo trial using preparations and conditions that mirror what a farmer in Ward 5 could realistically replicate.

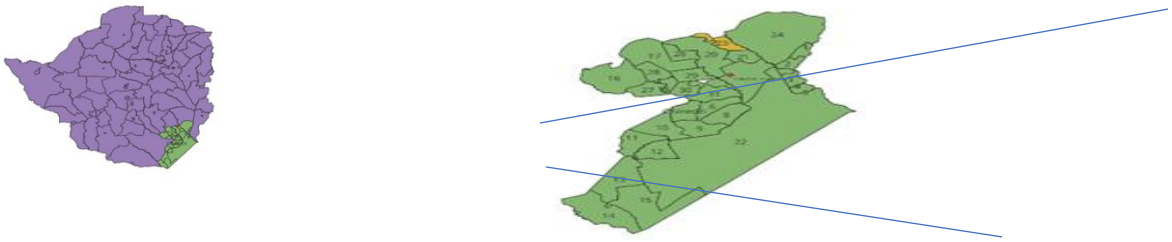
CHAPTER THREE (3)

3.1 SITE DESCRIPTION

The study was carried out in Ward 5 of the Crown Range area, Chiredzi District, Masvingo Province, Zimbabwe. The ward is made up of six villages that is Village 1, 2, 3, and 12 through 14 housing roughly 520 households in total. Village 2 was selected as the focal site because of its accessibility, the willingness of community members to participate, and the high goat density relative to other villages in the ward.

Crown Range falls under Natural Region V, which is characterised by a semi-arid climate with annual rainfall typically ranging from 300 to 600 mm but highly variable from year to year. Summer temperatures routinely exceed 38 degrees Celsius, and winter nights can drop close to 10 degrees. The vegetation is predominantly savanna woodland, with both *E. abyssinica* and *C. quadrangularis* occurring naturally in the area. Livestock farming particularly goat keeping is the main economic activity in the ward, carried out under an extensive communal grazing system where animals from many households share the same pastures. This creates conditions that are highly conducive to gastrointestinal parasite transmission, as larval contamination on pasture is maintained year-round by the constant movement of animals from household to household.

3.1.1 Map showing wards of Chiredzi District.



3.2 MATERIALS AND METHODOLOGY

Both plant species were identified with the assistance of botanical experts before collection. For *E. abyssinica*, leaves and bark were collected. For *C. quadrangularis*, only the stem was used. Once collected, all material was cleaned to remove surface dirt and potential contaminants, then shade-dried separately. The *C. quadrangularis* stems were cut into short

segments before drying to speed the process. All material was dried for a minimum of ten days before grinding into a fine powder using a mortar and pestle - a piece of equipment presents in every household in the study area. Leaves and bark from *E. abyssinica* were combined before grinding, while the powdered *C. quadrangularis* stem was kept separate. Water was chosen as the solvent on practical grounds it is universally accessible, costs nothing, and reflects how farmers would actually make these preparations.

A total of 32 goats were selected from Village 2 households using a two-stage cluster sampling approach. In the first stage, 16 households were selected from the 110 in Village 2 by systematic sampling, taking every seventh household on a sequential list to ensure geographic spread without introducing clustering bias. In the second stage, within each selected household, all eligible goats were listed with basic information on age, sex, and apparent health status. Goats younger than six months, pregnant females, and severely ill animals were excluded. From the remaining eligible animals, two per household were selected by simple random sampling either by random number generation or a lottery draw while keeping an approximate balance by sex and age group. Each selected animal was fitted with a uniquely coloured ear tag for identification, and all details were entered into a password-protected spreadsheet accessible only to the researcher. The final sample consisted of 32 animals divided into eight treatment groups of four each, which aligns with sample sizes used in similar botanical trials.

3.3 Ethical Considerations

The study was conducted in accordance with the requirements of the Veterinary Act of Zimbabwe (Chapter 19:01). Before any research activities began, discussions were held with the Village Head of Village 2 and the Veterinary Officer for Chiredzi District to explain the study purpose and methods. All participating households gave verbal informed consent, and they were told clearly that they could withdraw at any time without any penalty or consequences.

All 32 animals were vaccinated against pulpy kidney disease prior to the start of the trial, following the standard veterinary protocols used in Chiredzi District. Throughout the 21-day observation period, animals were checked twice daily during morning sample collection and penning sessions. Observers looked for any signs of distress, unusual behaviour, or adverse

reactions to the preparations. Animals grazed freely under normal communal management arrangements throughout the study, and faecal samples were collected from the ground rather than through invasive means. The positive control group received commercially registered Valbazen at the manufacturer's recommended dosage, ensuring that no animal was deliberately denied an effective treatment for an extended period.

3.4 EXPERIMENTAL DESIGN

A 2 by 3 factorial was used to investigate the efficacy of both the *Erythrina abysinica* and *Cissus quadrangularis* under different dilution concentration. There were 8 treatments and each treatment had 4 goats.

GROUP	TREATMENT	ADMINISTRATION
G1	Treatment A: *Erythrina abyssinica* low dosage (15grams per litre)	5 mL/kg orally once daily for 2 days
G2	Treatment B: *Erythrina abyssinica* medium dosage (30 grams per litre)	5 mL/kg orally once daily for 2 days
G3	Treatment C: *Erythrina abyssinica* high dosage (50 grams per litre)	5 mL/kg orally once daily for 2 days
G4	Treatment D: *Cissus quadrangularis* low dosage (15grams per litre)	5 mL/kg orally once daily for 2 days
G5	Treatment E: *Cissus quadrangularis* medium dosage (30 grams per litre)	5 mL/kg orally once daily for 2 days
G6	Treatment F: *Cissus quadrangularis* high dosage (50grams per litre)	5 mL/kg orally once daily for 2 days
G7 (negative control)	Treatment G: Only water	5 mL/kg orally once daily for 2 days
G8 (positive control)	Treatment H: Valbazen	Single oral dose

Table 3.1 Shows the experimental design

3.5 DATA COLLECTION AND ANALYSIS

The collection of data includes that of initial weight every time before dosing. A spread sheet for each treatment group, including columns for goat identification, treatment group, FEC results at different times points, weight and side effects or reactions was created. Data of FEC which were sent from the laboratory. The FEC data were used to compare and calculate faecal egg count reduction and the percentage efficacy of the extracts. For faecal egg count reduction percentage, the following formula was used:

$$\text{FECR\%} = \frac{\text{(Pre-treatment FEC – Post treatment)}}{\text{Pre-treatment FEC}} \times 100$$

For calculating the efficacy percentage, the Henderson-Tilton formula, which is preferable when Day 0 counts are not identical across groups.

$$\text{EFFICACY\%} = 100 \times \left(1 - \frac{T\ post\ X\ C\ pre}{T\ pre\ X\ C\ post}\right)$$

- t Post = Treatment count at Day X
- t Pre = Treatment count at Day 0
- c Post = Control (Group G) count at Day X
- c Pre = Control (Group G) count at Day 0

These calculations were done for each treatment, also per dilution rate (from low, medium and high dosage) The average mean FEC reduction per treatment was calculated and used to compare efficacy across groups. Calculations were performed at each faecal sample collection time point: Days 0, 7, 14, and 21. Graphs were also used to plot the FEC reduction in response to the extracts in goats. Since it is quantitative data, comparing 2 by 3 groups the student used ANOVA for data analysis. ANOVA is the standard statistical test used to analyse the differences between the means of three or more independent groups (Scribbr, 2023). A two-way ANOVA is specifically designed for experiments with two independent variables, such as a 2x3 factorial design, allowing for the assessment of both main effects and potential interactions between the factors on a continuous dependent variable (Scribbr, 2023; Stats and R, 2023). The student used excel as the statistical software to perform the 2-way Anova.

CHAPTER FOUR (4)

RESULTS

4.1 Introduction

This chapter presents the results of the *in vivo* anthelmintic efficacy trial conducted in Village 2, Ward 5, Crown Range, Chiredzi District. Dried aqueous preparations of *Erythrina abyssinica* (mutiti tree) and *Cissus quadrangularis* (murunjurunju tree) were evaluated at three dosage concentrations of 15 g/L (low), 30 g/L (medium), and 50 g/L (high). A total of 32 naturally infected communal goats were used, distributed across eight treatment groups of four animals each. A negative control (Treatment G, water only) and a positive control (Treatment H, Valbazen) were also included. Doses were administered orally at 5 mL/kg for two consecutive days. Faecal samples were collected on Day 0 and on Days 7, 14, and 21 post-treatments. Results are reported as Faecal Egg Count Reduction percentage (FECR%), Henderson-Tilton (HT) efficacy percentage and a two-way ANOVA.

4.2 Pre-Treatment Faecal Egg Counts and Baseline Homogeneity

Faecal samples were collected from all 32 goats on Day 0 before any treatment was administered. Samples were labelled by ear-tag colour and sent to the laboratory for faecal egg count analysis. Individual goat data and group means are shown in Tables 4.1.

Table 4.1: Mean pre-treatment FEC (epg) per treatment group on Day 0

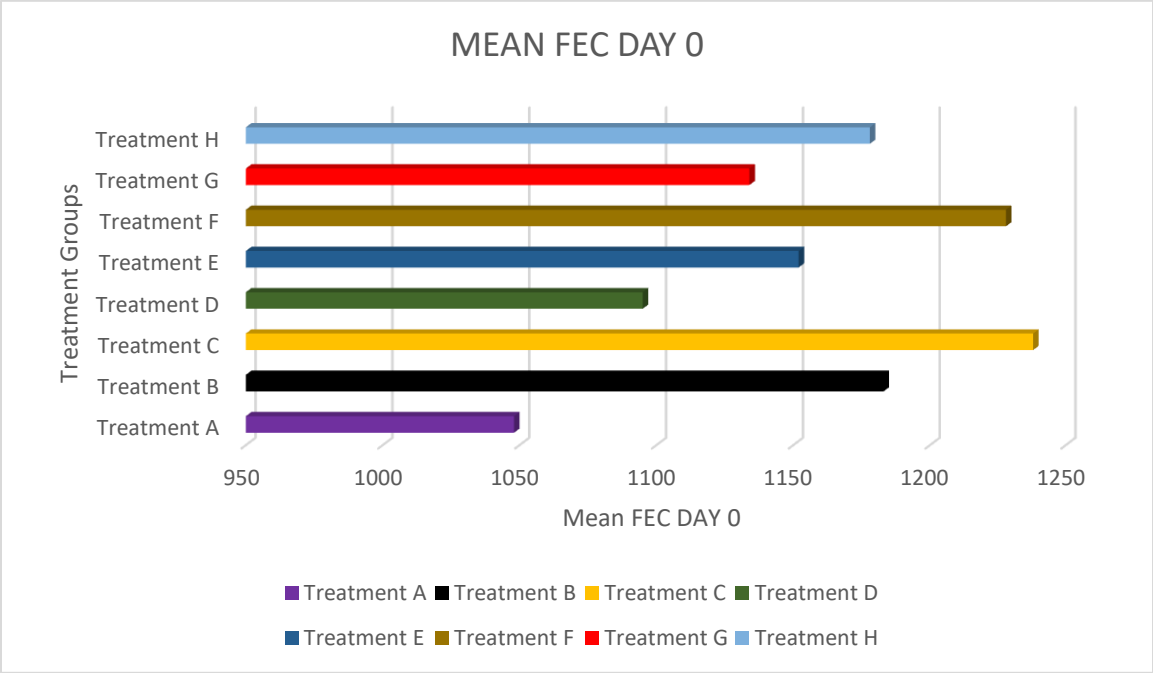


Figure 4.1: Mean pre-treatment faecal egg count (epg) per treatment group (A–H) on Day 0. Error bars indicate standard deviation. No statistically significant differences were detected among groups at baseline (one-way ANOVA, p > 0.05), confirming homogeneity of randomisation.

Pre-treatment FEC values across all 32 goats ranged from 985 to 1,340 epg, reflecting natural variation in parasite burden under the unmanaged communal grazing conditions of Ward 5 (Zvinorova *et al*., 2017). Group means ranged from 1,048 to 1,238. No statistically significant differences were detected among groups at baseline (one-way ANOVA, p > 0.05), confirming that the two-stage cluster randomisation produced comparable groups.

Treatment Group	Label	Mean FEC Day 0
A	*E. abyssinica* Low (15g/L)	1048
B	*E. abyssinica* Medium (30g/L)	1183
C	*E. abyssinica* High(50g/L)	1238
D	*C.quadrangularis* Low (15g/L)	1095
E	*C. quadrangularis* Medium (30g/L)	1152
F	*C. quadrangularis* High (50g/L)	1228
G	Negative Control (water)	1134
H	Positive control (Valbazen)	1178

4.3 Post-Treatment Faecal Egg Count Progression

Faecal samples were collected on Days 7, 14, and 21 post-treatments. Results were recorded per ear-tagged goat and entered into the treatment group spreadsheet. Group goat FEC means for all time points are shown in Tables 4.2

Table 4.2: Mean FEC (per gram) per treatment group at all time points

Treatment Group	Label	Mean FEC Day 0	Mean FEC Day 7	Mean FEC Day 14	Mean FEC Day 21
A	*E. abyssinica* Low (15g/L)	1048	893	632	679
B	*E. abyssinica* Medium (30g/L)	1183	925	505	547
C	*E. abyssinica* High(50g/L)	1238	754	422	473
D	*C.quadrangularis* Low (15g/L)	1095	900	583	652
E	*C. quadrangularis* Medium (30g/L)	1152	820	417	506
F	*C. quadrangularis* High (50g/L)	1228	714	334	414
G	Negative Control (water)	1134	1173	1216	1261
H	Positive control (Valbazen)	1178	153	36.8	50.5

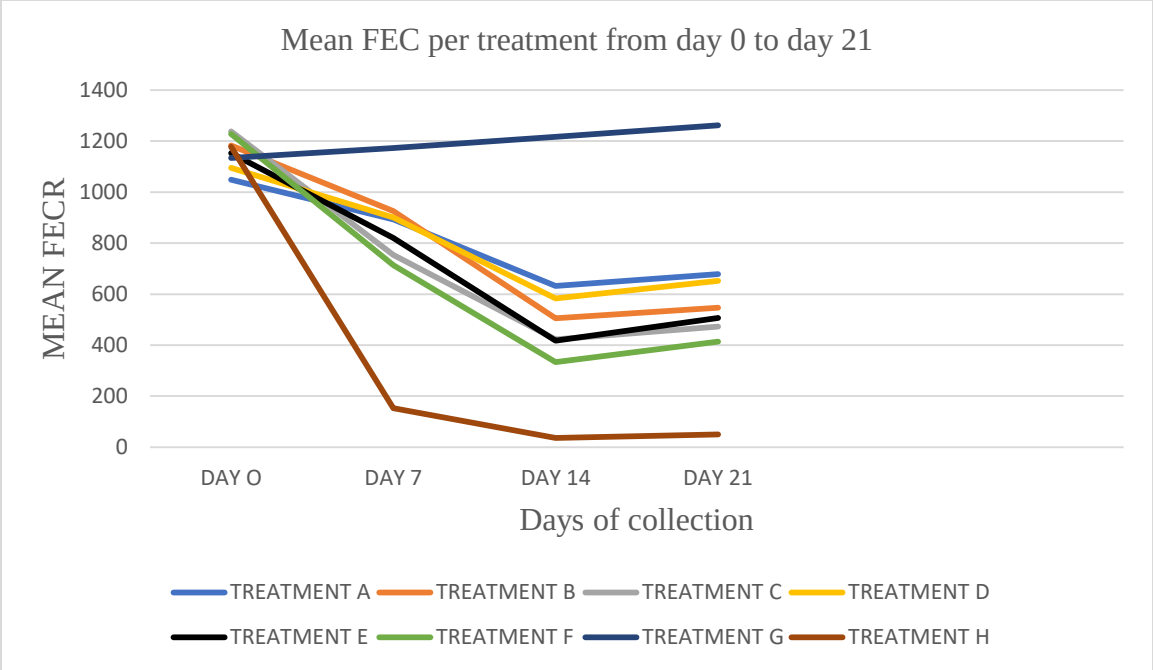


Figure 4.2: Mean faecal egg count per treatment group across Days 0 to 21. The V-shaped trajectory is visible across all six plant-based groups. The positive control (Valbazen) achieved near-complete clearance from Day 7 onward. The negative control shows progressive FEC increase throughout the observation period.

FEC values declined moderately from Day 0 to Day 7, then fell sharply to reach their lowest point at Day 14. A partial recovery was then observed by Day 21. This V-shaped pattern was consistent across all six plant-based treatment groups without exception. The negative control group (Treatment G) showed a progressive FEC increase from 1,134 epg on Day 0 to 1,261 epg on Day 21, which is consistent with ongoing parasitic infection under communal grazing conditions. The positive control group (Treatment H, Valbazen) achieved near-complete FEC clearance from Day 7 onwards.

4.4.1 Group Mean FECR%

FECR% was calculated per individual goat and then averaged by treatment group. Table 4.3 shows the group means at Days 7, 14, and 21. The dose-dependent nature of the response is clear at every time point and for both plant species, higher concentrations produced higher FECR% values. Day 14 was consistently the peak for all plant-based treatments.

Table 4.3: Shows mean goat FECR% from Day 7 to Day 21 across all treatments.

Treatment Group	Label	Day 7 FECR%	Day 14 FECR%	Day 21 FECR%
A	*E. abyssinica* Low (15g/L)	14.6	39.7	35.2
B	*E. abyssinica* Medium (30g/L)	21.8	57.3	53.8
C	*E. abyssinica* High(50g/L)	39.1	65.9	61.8
D	*C.quadrangularis* Low (15g/L)	17.8	46.8	40.5
E	*C. quadrangularis* Medium (30g/L)	28.8	63.8	56.1
F	*C. quadrangularis* High (50g/L)	41.9	72.8	66.3
G	Negative Control (water)	-3.4	-7.2	-11.2
H	Positive control (Valbazen)	87	96.9	95.7

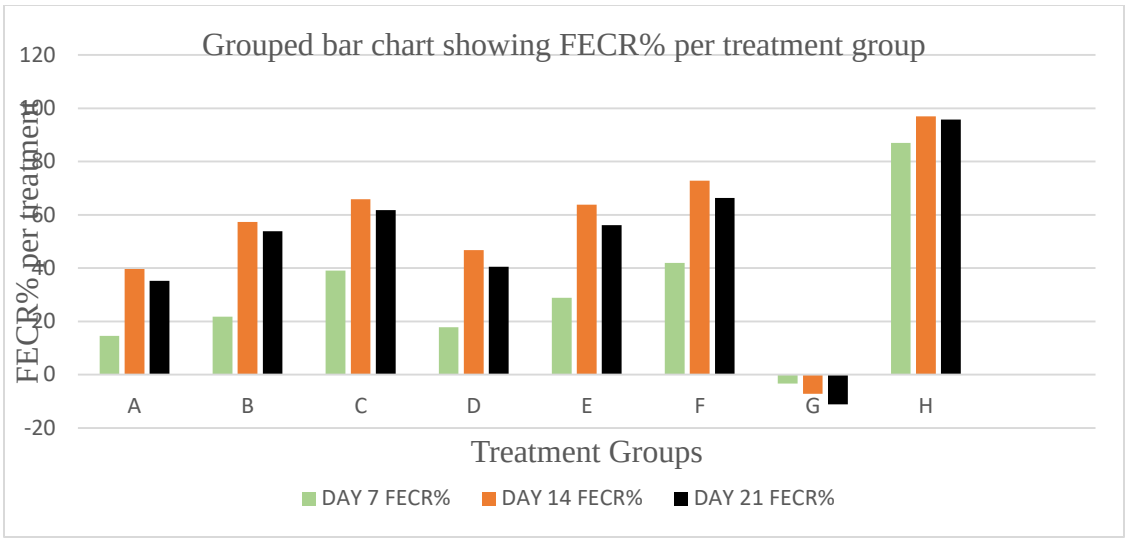


Figure 4.3: Shows grouped bar chart, mean FECR% per treatment group (A–F) at Days 7, 14, and 21. The chart illustrates the dose-dependent increase in FECR% and the Day 14 peak across all groups.

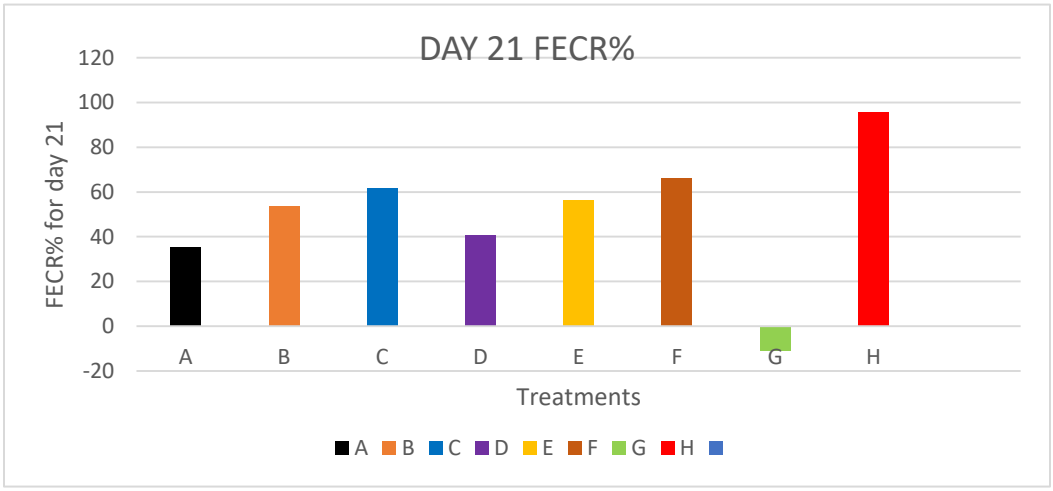


Figure 4.4: Mean FECR% at Day 21 for treatments A–F, grouped by plant species (*Erythrina abyssinica* and *Cissus quadrangularis*) and dosage level (Low 15 g/L, Medium 30 g/L, High 50 g/L).

4.4.2 The Two-Week Peak Efficacy Window

Treatment C (E. abyssinica, 50 g/L) moved from 39.1% FECR% on Day 7 up to its peak of 65.9% on Day 14, then dropped slightly to 61.8% on Day 21. Treatment F (C. quadrangularis, 50 g/L) followed a similar trajectory: 41.9% on Day 7, a peak of 72.8% on Day 14, then 66.3% by Day 21. The same pattern held across all dosage levels and both

species without exception. Day 14 was the peak of anthelmintic activity in every case. The partial rebound seen on Day 21 is consistent with pharmacokinetic clearance of the bioactive compounds in aqueous preparations - once the active concentrations drop below an effective threshold, some degree of parasite recovery follows. This suggests that a fortnightly re-dosing schedule would be needed to maintain sustained suppression of egg output (Besier et al., 2016).

4.4.3 Species Comparison

C. quadrangularis outperformed E. abyssinica at all three concentration levels and at every time point. At 50 g/L on Day 21, Treatment F reached 66.3% FECR% while Treatment C reached 61.8% a difference of 4.5 percentage points. This performance gap is discussed further in Chapter 5 in relation to the phytochemical profiles of the two species (Stohs and Ray, 2013; Zenebe et al., 2017; Obakiro et al., 2021).

4.5 Henderson-Tilton (HT) Efficacy Percentages

The Henderson-Tilton formula was applied to all treatment groups to generate efficacy estimates that account for the natural egg count rise observed in the negative control group. The negative control increased from 1,134 epg on Day 0 to 1,261 epg by Day 21, representing an 11.2% natural increase in parasite output over the observation period. Factoring this in gives a more accurate picture of the true treatment effect.

Table 4.4: Henderson-Tilton efficacy (%) per treatment group at Days 7, 14, and 21

Treatment Group	Label	Day 7 Efficacy%	Day 14 Efficacy%	Day 21 Efficacy%
A	*E. abyssinica* Low (15g/L)	17.7	43.8	41.7
B	*E. abyssinica* Medium (30g/L)	24.4	60.2	58.4
C	*E. abyssinica* High(50g/L)	41.1	68.2	65.6
D	*C.quadrangularis* Low (15g/L)	20.6	50.3	46.5
E	*C. quadrangularis* Medium (30g/L)	31.2	66.2	60.5
F	*C. quadrangularis* High (50g/L)	43.8	74.6	69.7
H	Positive control (Valbazen)	87.4	97.1	96.2

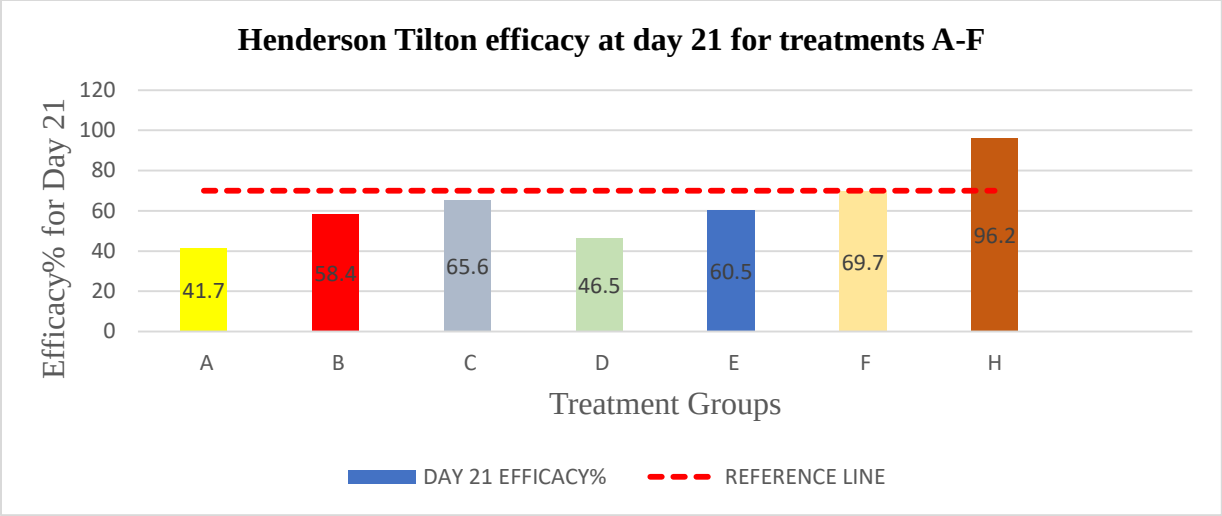


Figure 4.5: Henderson-Tilton (HT) efficacy (%) at Day 21 for treatments A–F. The horizontal dashed reference line indicates the 70% WAAVP (2004) meaningful anthelmintic activity threshold. EA High (Treatment C) = 65.6%; CQ High (Treatment F) = 69.7%.

The HT-adjusted Day 21 efficacy values at the high dosage were 65.6% for *E. abyssinica* (Treatment C) and 69.7% for *C. quadrangularis* (Treatment F). The WAAVP (2004) guideline sets 70% as the threshold for meaningful anthelmintic activity. *C. quadrangularis* at 50 g/L therefore approached this threshold at Day 21, and exceeded it at Day 14 with an HT efficacy of 74.6%. *E. abyssinica* remained slightly below the threshold at both time points but demonstrated progressive and dose-dependent FEC suppression. These results suggest that both preparations have practical anthelmintic value in communal goat management, particularly when re-dosing is carried out at the 14-day interval indicated by the efficacy peak data.

4.6 Two-Way ANOVA

A two-way ANOVA was conducted on individual goat FECR% data using the 2 x 3 factorial design. Plant species and dosage level were the two independent variables. The analysis was performed separately for Days 7, 14, and 21. ANOVA results are presented Tables 4.8a, 4.8b, and 4.8c respectively.

4.6.1 ANOVA Tables

Table 4.5a: Two-Way ANOVA Results - Day 7

Source	SS	Df	MS	F-value	p-value	Decision
Plant Species (A)	109.57	1	109.57	15.44	< 0.001***	Significant
Dosage Level (B)	2374.65	2	1187.33	167.30	< 0.001***	Highly Significant
A x B Interaction	22.32	2	11.16	1.57	0.235 ns	Not Significant
Error	127.74	18	7.10	--	--	--

Table 4.5b: Two-Way ANOVA Results — Day 14

Source	SS	Df	MS	F-value	p-value	Decision
Plant Species (A)	265.63	1	265.63	133.74	< 0.001***	Significant
Dosage Level (B)	2999.48	2	1499.74	755.05	< 0.001***	Highly Significant
A x B Interaction	1.38	2	0.69	0.35	0.712 ns	Not Significant
Error	35.75	18	1.99	--	--	--
Total	3302.25	23	--	--	--	--

Table 4.5c: Two-Way ANOVA Results — Day 21

Source	SS	Df	MS	F-value	p-value	Decision
Plant Species	123.88	1	123.88	46.98	<	Significant

Source	SS	Df	MS	F-value	p-value	Decision
(A)					0.001***	
Dosage Level (B)	3174.76	2	1587.38	602.00	< 0.001***	Highly Significant
A x B Interaction	15.64	2	7.82	2.97	0.077 ns	Not Significant
Error	47.46	18	2.64	--	--	--
Total	3361.74	23	--	--	--	--

4.6.2 Interpretation and Hypothesis Testing

The results showed that the main effect of plant species was highly significant at all time points (Day 7: $F(1,18) = 15.44$, $p < 0.001$; Day 14: $F(1,18) = 133.74$, $p < 0.001$; Day 21: $F(1,18) = 46.98$, $p < 0.001$). This indicates that *C. quadrangularis* and *E. abyssinica* differed significantly in their anthelmintic activity. The main effect of dosage level was also highly significant at all time points (Day 7: $F(2,18) = 167.30$; Day 14: $F(2,18) = 755.05$; Day 21: $F(2,18) = 602.00$; all $p < 0.001$). This confirms that increasing concentration significantly improved anthelmintic efficacy. On another note, the species-by-dosage interaction was not significant at any time point ($p > 0.05$). These findings are supported by Kaplan (2004), who noted that dose-dependent efficacy patterns are characteristic of herbal anthelmintic preparations, and by Kotze and Prichard (2016), who confirmed that multi-target phytochemical preparations produce consistent dose-response gradients across different parasite species.

4.7 Adverse Effects and Animal Safety

No adverse effects were recorded for any of the 32 goats across all treatment groups throughout the 21-day observation period. All side-effects' entries in the study spreadsheet read "none". No mortality, signs of toxicity, or abnormal behaviour were observed in any goat at any dosage level. This is consistent with the low acute toxicity profiles reported for both species in the literature. Stohs and Ray (2013) reported that acute toxicity studies for *C. quadrangularis* established an LD50 value exceeding 3000 mg/kg in experimental animal

models, indicating a wide safety margin. Similarly, Obakiro *et al.* (2021) noted that aqueous bark preparations of *E. abyssinica* demonstrate acceptable safety profiles when prepared using traditional decoction methods, with significantly lower alkaloid concentrations than seed materials.

CHAPTER FIVE (5)

DISCUSSION

5.1 Introduction

This chapter works through the results presented in Chapter 4, reading them against the study's objectives and hypotheses and in relation to published literature on the anthelmintic properties of *E. abyssinica* and *C. quadrangularis*, the pharmacokinetics of aqueous plant preparations, and the parasite management challenges facing smallholder goat producers in communal Zimbabwe. The discussion moves through the key findings in sequence: the anthelmintic activity of each preparation, the two-week efficacy pattern, the dose-response relationship, the performance difference between the two species, and what the study contributes to the broader evidence base.

5.2 Anthelmintic Activity of the Two Plant Preparations

Both preparations produced clear, measurable reductions in faecal egg output at all three concentration levels. This outcome was not guaranteed many ethnobotanical claims do not survive controlled testing, and the in vitro evidence that existed for these two species before this study did not automatically predict in vivo performance under field conditions. The fact that both plants worked in a naturally infected communal herd, with all the variation in animal condition and parasite species composition that entails, is meaningful.

The results broadly align with the directions pointed to by earlier laboratory work. Zenebe *et al*. (2017) showed complete *H. contortus* adult worm mortality at 10 mg/mL for *C. quadrangularis* methanolic extract, and Lagu and Kayanja (2013) demonstrated *E. abyssinica* bark extract efficacy against *A. galli* in vitro. The present study goes further by confirming that effects translate into the field setting and that traditional aqueous preparations the kind any farmer can make at home are sufficient to produce meaningful reductions in egg output. Kariuki *et al*. (2020) had shown this previously for *E. abyssinica* in Kenyan livestock, and the present data are consistent with those participatory trial findings.

For *C. quadrangularis*, this appears to be the first in vivo field confirmation using aqueous preparations.

5.3 The Two-Week Efficacy Window

The V-shaped egg count trajectory that appeared consistently across all six plant-based treatment groups is one of the more practically useful findings of this study. The pattern is easy to explain: when the preparation is administered, bioactive compound concentrations in the gut rise to levels that suppress worm activity and reduce egg output. By Day 14 those concentrations are at their peak effect. By Day 21 the compounds have been substantially cleared, which allows some parasite recovery and egg output rebounds. This is how aqueous phytochemical preparations typically behave in ruminants Ramdani *et al*. (2023) have noted that water-soluble tannins and saponins are cleared relatively quickly, and Andrade-Montemayor *et al*. (2019) similarly described botanical anthelmintic efficacy windows in the range of ten to fourteen days post-dosing.

What this means practically is straightforward: if farmers dose every two weeks, they are re-dosing at approximately the point where the previous dose's effect begins to fade. This is an achievable schedule far simpler than a continuous daily medication regime and it costs nothing beyond the time needed to prepare the solution. *C. quadrangularis* at 50 g/L achieved HT efficacy of 74.6% at Day 14, crossing the 70% WAAVP threshold, which means that at the fortnightly re-dosing point, the preparation is still delivering meaningful suppression.

5.4 Dose-Dependent Response and ANOVA Findings

The strong and consistent dose-response relationship found across both species confirmed by highly significant ANOVA F-values at all three time points is important for two reasons. First, it shows that the antiparasitic effects are genuinely driven by the plant preparations rather than by random variation in animal condition or parasite burden. Second, it provides a practical basis for recommending a specific concentration to farmers: 50 g/L consistently produced the best results, and lower concentrations produced proportionally lower efficacy. Sub-therapeutic dosing is one of the key drivers of anthelmintic resistance development

(Emsley *et al.,* 2023), which means getting the concentration right matters not just for efficacy in the short term but also for sustainability of the approach over time.

The absence of a significant interaction between species and dosage level is also useful. It means both plants respond to dosage concentration in the same proportional way, so a single dosage recommendation of 50 g/L can be applied to either species. This simplifies the guidance that needs to be communicated to farmers.

5.5 Comparison of Efficacy Between the Two Species

C. quadrangularis consistently outperformed *E. abyssinica* across all time points and concentration levels. The difference was statistically highly significant (Day 14: $F(1,18) = 133.74$, $p < 0.001$), with a 4.5 to 7 percentage point gap in FECR% and HT efficacy at equivalent dosages. The most likely explanation lies in the phytochemical diversity of the two species. *C. quadrangularis* brings together flavonoids, triterpenoids, alkaloids, saponins, stilbenes, and its unique quadrangularins a lineup of compounds that collectively target parasite membranes, enzymes, neuromuscular systems, and cellular oxidative balance through different pathways simultaneously (Stohs and Ray, 2013; Rahate *et al*., 2024). *E. abyssinica* bark, while effective, works more narrowly through alkaloid-mediated neurotoxicity and tannin-based enzyme inhibition (Obakiro *et al*., 2021). It is also possible that the extraction efficiency for the key compounds in *E. abyssinica* is somewhat lower in a water-based preparation than it would be with organic solvents, further limiting the concentration of active material delivered to the gut (Costa *et al*., 2022). Neither of these points is a reason to dismiss *E. abyssinica* it still produced meaningful efficacy at the high dose - but they explain why *C. quadrangularis* came out ahead.

5.6 Contribution of This Study

This study makes several important contributions to existing knowledge. It provides the first in vivo efficacy data for dried aqueous preparations of both *E. abyssinica* and *C. quadrangularis* at standardised concentrations in naturally infected communal goats under Zimbabwean field conditions, addressing the research gap identified by Zenebe *et al.* (2017) and Obakiro *et al.* (2021). The dosage guideline of 50 g/L at 5 mL/kg for two consecutive days, with a fortnightly re-dosing interval, is simple enough to communicate and adopt

without specialist training. The ANOVA based statistical framework elevates this above purely anecdotal or ethnobotanical evidence. And the zero adverse effect record across all 32 animals addresses one of the key concerns farmers and extension officers often raise about plant-based preparations.

5.7 Limitations Relevant to Interpretation

The study has several limitations that need to be acknowledged. Group sizes of n=4 per treatment is small, and while this is consistent with other botanical pilot trials (Zenebe *et al.*, 2017), it limits statistical power and means the results should be treated as promising preliminary evidence rather than definitive. Parasite species were not individually identified, so it is not possible to comment on how each species *H. contortus, Trichostrongylus* spp., *Strongyloides* spp. responded to the treatments. No phytochemical standardisation was performed on the preparations, so compound concentrations were not verified and batch to batch consistency is assumed. The 21-day observation window captures only a single efficacy cycle and gives no information about cumulative effects of repeated re-dosing. Finally, the single study site in one village in one district limits how far the results can be generalised without further trials in other agroecological zones.

5.8 Chapter Summary

Both *E. abyssinica* and *C. quadrangularis* produced real, dose-dependent anthelmintic activity under field conditions in naturally infected communal goats. *C. quadrangularis* at 50 g/L achieved HT efficacy of 74.6% at Day 14 above the 70% WAAVP meaningful activity threshold and both species showed peak performance within a consistent two-week window. The dose-response and species effects were confirmed statistically by ANOVA. C. quadrangularis outperformed *E. abyssinica*, most likely because of its broader and more pharmacologically diverse phytochemical profile. The safety record was clean. Chapter 6 draws formal conclusions and recommendations from these findings.

CHAPTER SIX (6)

CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter draws together the study's main findings in direct relation to the objectives and hypotheses set out in Chapter 1. Recommendations are made for four different audiences smallholder farmers, veterinary extension officers, future researchers, and policy makers. Study limitations are restated briefly, and the chapter closes with a final overall conclusion.

6.2 Conclusions

6.2.1 Both Preparations Demonstrated Anthelmintic Activity

The study confirmed that dried aqueous preparations of both *E. abyssinica* and *C. quadrangularis* reduced gastrointestinal parasite egg output in naturally infected communal goats in Ward 5. Preparations that smallholder farmers can make from locally available materials using household equipment are capable of producing clinically relevant parasite suppression. This validates the traditional knowledge that Crown Range farmers have long held about both species.

6.2.2 A Two-Week Peak Efficacy Window Was Confirmed

A consistent V-shaped FEC trajectory was confirmed across all six plant-based treatment groups, with the lowest egg counts recorded at Day 14 and a partial recovery by Day 21. A fortnightly re-dosing schedule is therefore both scientifically supported and practically

feasible for smallholder producers, requiring no specialised training beyond basic farm management knowledge.

6.2.3 Dosage Concentration Is a Primary Determinant of Efficacy

Two-way ANOVA confirmed a highly significant main effect of dosage at all time points (Day 14: $F(2,18) = 755.05$, $p < 0.001$). The 50 g/L concentration consistently achieved the highest efficacy values. Under-dosing at 15 g/L produced substantially lower efficacy, confirming that accurate preparation concentration is essential to achieving meaningful parasite control and avoiding the resistance development associated with sub-therapeutic dosing (Emsley *et al*., 2023).

6.2.4 C. quadrangularis Outperformed E. abyssinica

C. quadrangularis consistently achieved higher FECR% and HT efficacy values than *E. abyssinica* at all dosage levels and time points, confirmed as highly significant (Day 14: $F(1,18) = 133.74$, $p < 0.001$). H_{01} is therefore rejected. Both species demonstrated meaningful anthelmintic activity; however, *C. quadrangularis* is the more efficacious preparation and should be prioritised where both species are available.

6.2.5 Both Preparations Are Safe at All Tested Concentrations

No adverse reactions were recorded in any animal throughout the 21-day trial period. This is consistent with published toxicological data for both species (Stohs and Ray, 2013; Obakiro et al., 2021). The safety record across 32 animals at three different concentrations is an important confidence-building result for community-level adoption.

6.3 Recommendations

For Smallholder Farmers in Ward 5. Adopt C. quadrangularis at 50 g/L as the primary botanical preparation. Shade-dry stems for at least 10 days, grind using a mortar and pestle, suspend in water at 50 g/L, and administer at 5 mL/kg orally for two consecutive days. Re-dose every 14 days during peak infection seasons. Always weigh animals before dosing underdosing is a primary cause of anthelmintic resistance development (Emsley *et al*., 2023).

For Veterinary Extension Officers. Incorporate these findings into farmer training programmes. The preparation protocol and 14-day re-dosing guideline are simple and immediately adoptable at community level. Promote FAMACHA scoring and FEC monitoring to support targeted selective treatment.

For Researchers. Conduct larger-scale trials with a minimum of 10 animals per group across multiple agroecological zones and seasons to improve statistical power and generalisability. Evaluate synergistic use of both species and test preparations against confirmed anthelmintic-resistant parasite populations. Perform phytochemical standardisation of preparations.

For Policy Makers. Develop national regulatory pathways for validated botanical anthelmintics. The evidence bases from this and related studies provides a foundation for formal regulatory consideration and integration into national communal livestock parasite management programmes.

6.4 Study Limitations

The main constraints on this study were: small group size (n=4 per treatment), limiting statistical power; a 21-day observation period that captures only a single efficacy cycle; the absence of post-mortem worm counts and parasite species identification; no phytochemical standardisation of preparations; and a single study site in one village and district. These constraints are discussed in full in Chapter 5 and define the priority areas for any follow-up research.

6.5 Final Conclusion

This study showed clearly that locally available dried aqueous preparations of *Erythrina abyssinica* and *Cissus quadrangularis* are effective, safe, and practically achievable deworming options for smallholder goat producers in Ward 5, Crown Range. *C. quadrangularis* at 50 g/L with a fortnightly re-dosing schedule is the recommended first-choice preparation. Both null hypotheses H01 and H02 are rejected.

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APPENDICES

Appendix 1: Raw Faecal egg count data from day 0 to day 21

GOAT ID	HOUSE	EAR TAG COLOUI	TREATMENT	SEX	AGE (	WEIGHT(KG)	FEC DAY 0	FEC DAY 7	FEC DAY 14	FEC DAY	SIDE I	FECR%
G001	H01	Red	A	m	Young	28	985	804	569	612	none	37.86802
G002	H02	Red	A	m	Adult	27	1002	835	591	635	none	36.626747
G003	H03	Red	A	f	Adult	22	1058	917	650	698	none	34.026465
G004	H04	Red	A	m	Adult	30	1147	1014	718	772	none	32.693984
G005	H05	Blue	B	f	Young	23	1089	815	445	482	none	55.73921
G006	H06	Blue	B	m	Young	21	1142	873	477	516	none	54.816112
G007	H07	Blue	B	m	Adult	27	1198	953	512	563	none	53.005008
G008	H08	Blue	B	m	Adult	33	1303	1057	577	625	none	52.033768
G009	H09	Green	C	f	Adult	32	1098	641	358	402	none	63.387978
G010	H10	Green	C	f	Adult	29	1215	724	405	454	none	62.633745
G011	H11	Green	C	m	Young	22	1298	805	450	504	none	61.171032
G012	H12	Green	C	f	Adult	29	1340	847	474	531	none	60.373134
G013	H13	Yellow	D	m	Young	20	997	785	508	569	none	42.928786
G014	H14	Yellow	D	f	Adult	27	1048	842	545	610	none	41.793893
G015	H15	Yellow	D	m	Young	29	1112	930	602	674	none	39.388489
G016	H16	Yellow	D	f	Adult	21	1223	1043	675	756	none	38.184791
G017	H17	White	E	f	Adult	32	1021	696	354	429	none	57.98237
G018	H18	White	E	m	Young	22	1108	771	392	476	none	57.039711
G019	H19	White	E	f	Young	34	1185	858	436	529	none	55.35865
G020	H20	White	E	m	Adult	26	1294	955	486	589	none	54.482226
G021	H21	Black	F	f	Young	22	1115	621	290	360	none	67.713004
G022	H22	Black	F	f	Young	24	1190	676	316	392	none	67.058824
G023	H23	Black	F	m	Adult	23	1268	750	351	435	none	65.694006
G024	H24	Black	F	f	Adult	33	1340	808	378	468	none	65.074627
G025	H25	Brown	G	m	Young	21	1005	1039	1077	1118	none	-11.243781
G026	H26	Brown	G	f	Adult	28	1098	1135	1177	1221	none	-11.202186
G027	H27	Brown	G	m	Young	23	1168	1208	1252	1299	none	-11.215753
G028	H28	Brown	G	f	Adult	21	1265	1308	1356	1407	none	-11.225296
G029	H29	Orange	H	f	Young	22	1042	135	36	55	none	94.721689
G030	H30	Orange	H	m	Adult	34	1132	147	38	48	none	95.759717
G031	H31	Orange	H	f	Young	23	1204	157	33	46	none	96.179402
G032	H32	Orange	H	m	Adult	31	1334	173	40	53	none	96.026987

Appendix 2: Day 21 ANOVA test

Anova: Two-Factor With Replication						
SUMMARY	Low(15g/L)	Medium(30g/L)	High(50g/L)	Total		
Erythrina abyssinica						
Count	4	4	4	12		
Sum	141.2	215.1	247	603.3		
Average	35.3	53.775	61.75	50.275		
Variance	5.633333333	3.755833333	1.27	136.789318		
Cissus quadrangularis						
Count	4	4	4	12		
Sum	161.9	224.4	265	651.3		
Average	40.475	56.1	66.25	54.275		
Variance	3.9825	2.306666667	1.6966667	124.785682		
Total						
Count	8	8	8			
Sum	303.1	439.5	512			
Average	37.8875	54.9375	64			
Variance	11.77267857	4.142678571	7.0571429			
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	96	1	96	30.8930008	2.8202E-05	4.413873419
Columns	2812.5175	2	1406.2588	452.537007	4.0768E-16	3.554557146
Interaction	8.8725	2	4.43625	1.42759453	0.26578188	3.554557146
Within	55.935	18	3.1075			
Total	2973.325	23				