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FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

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Evaluation of crude aqueous leaf extracts of *Tephrosia vogelii*, *Azadirachta indica* and *Cissus quadrangularis* on the control of fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in maize (*Zea mays*)



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A dissertation submitted in partial fulfillment of the requirements of the
Bachelor of Agricultural Science Honors Degree in Crop Science

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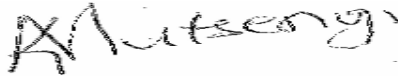
APPROVAL FORM

The undersigned certified that they have supervised and recommend to Bindura University of Science Education for acceptance of dissertation entitled **Evaluation of crude aqueous leaf extracts of *Tephrosia vogelii*, *Azadirachta indica* and *Cissus quadrangularis* on the control of fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in maize (*Zea mays*)** submitted by MURABWI MUFARO B in partial fulfillment of the Bachelor of Agricultural Science Honours Degree in Crop Science.

Supervisor

I have supervised the research project for the above-mentioned student and I am convinced that the research can be submitted.

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DECLARATION

I, Murabwi Mufaro Belinda do hereby declare that this project is a result of my original research work undertaken by myself, except where clearly and specifically acknowledged. This project has not been previously submitted in whole or in part for any degree or diploma at any other institution. It is being submitted in partial fulfillment of the requirements for the Bachelor of Agriculture Science Honours Degree in Crop Science at Bindura University of Science Education.

DEDICATION

I dedicate my project to my beloved parents, whose unwavering love, sacrifices and support have been the foundation of my success. Every milestone I have achieved is a reflection of their guidance and belief in me. Their unconditional love and endless sacrifices will forever be treasured, deeply appreciated and remembered throughout my life.

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ABSTRACT

Fall armyworm (*S. frugiperda*) is one of the major pests causing significant damage to maize leading to quality and yield losses for maize producers especially the smallholder farmers thereby threatening food security. The response to the pest mainly relies on synthetic pesticides which are often unaffordable to small-scale farmers. Excessive use of synthetic insecticides has raised concerns regarding environmental pollution, pest resistance and health hazards, hence the need to explore sustainable alternative pest management options. This study evaluated the effectiveness of locally available botanicals fish bean (*T. vogelii*), neem (*A. indica*) and veldt grape (*C. quadrangularis*) in the control of fall armyworm. The experiment was laid out in a Randomised Complete Block Design (RCBD) with five treatments (three botanicals, a positive and negative control) replicated four times. Data was analysed using the GenStat version 18 using Least Significant Difference (LSD) at 5% significance level. The results showed significant differences ($p < 0.001$) among treatments in pest incidence, leaf damage, plant height and grain yield. The positive control (Lambda-Cyhalothrin) was consistent and outperformed all the other treatments as it had the least pest incidence of 22.5%, 30%, 40%, 50% at 5, 6, 7 and 8 weeks respectively while the untreated control recorded highest pest incidence of 52.5%, 65%, 72.5% and 80% during same sampling periods. The untreated control recorded the highest leaf damage scores of 3.75, 5.25, 6.25 and 7 from week 5 to 8 respectively. Lambda-Cyhalothrin and *A. indica* produced taller plants and higher grain yields compared to other treatments. The study concluded that botanical extracts possess insecticidal properties capable of reducing fall armyworm incidence and leaf damage while improving maize growth and yield. Among the botanicals evaluated *A. indica* was the most effective, followed by *T. vogelii*, whereas *C. quadrangularis* showed comparatively lower effectiveness. These results suggest that *A. indica* has strong potential as an effective botanical pesticide for sustainable fall armyworm management, improved maize yields, and environmental protection in Zimbabwe.

Keywords: Fall armyworm, *T. vogelii*, *C. quadrangularis*, *A. indica*, Zimbabwe, smallholder farmers

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LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of variance
KG	Kilograms
FAW	Fall armyworm
LSD	Least significant difference
RCBD	Randomized complete block design
s.e.d	Standard errors of mean differences
M	Million
m	Metre
Ha	Hectare

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CHAPTER 1: INTRODUCTION

1.0 Background

The economy of Zimbabwe is agro-based and maize is the staple crop makes up about 14 and 20% to the Gross Domestic Product (GDP), which has a weight of 15-20% on national GDP (Chigombe, 2023) . Maize (*Zea mays L.*) is also one of the widely cultivated cereal crops in the world (FAO, 2023). It plays an important role in supporting rural livelihoods, ensuring food security and contributing to the national economy. Maize is not only important food crop for human consumption, but also a basic element of feed and raw material for manufacturing many industrial products such as alcoholic beverages and ethanol (Adiaha, 2017). Maize is grown in areas with 250mm to more than 5000mm of rainfall per year. It exhibits considerable versatility, enabling its cultivation across diverse agro-climatic zones but if the temperature is high or if the humidity is low maize will not perform well as these damages the foliage and hampers pollination there by resulting in poor grain. It has a relatively short growing season and a high yield potential making it one of the most widely produced crops. In Zimbabwe the majority of the producers are smallholder farmers.

Despite its importance, maize productivity is hindered by abiotic and biotic factors. The abiotic factors that affect maize production include salinity, sodicity and meteorological factors that is rainfall and temperature conditions. Maize production is also influenced by socio-economic challenges such as lack of capital to purchase fertilizers, improved varieties and other production inputs. In recent years biotic factors have become major constraints to maize production particularly, diseases, weeds and various insect pests. Among the insect pests affecting maize production, the fall armyworm has emerged as one of the most destructive pests worldwide whose larvae feeds on leaves, stems, tassels and ears causing significant direct and indirect damage(Harrison *et al.*, 2019).

S. frugiperda which is believed to be native to tropical regions of the Americas was introduced to Africa in 2016 (Prasanna, 2018).According to Harrison *et al.*, (2019) fall armyworm is a long-distance migratory pest, with the adult moths capable of flying distances over100km in a single night when conditions are favorable. The ability to disperse allows fall armyworms to colonise large areas in a short period of time. The female moths deposits over 2000 eggs underside of leaves(Harrison *et al.*, 2019). These pests are voracious feeders and polyphagous in nature they attack many important food crops in Africa. It attacks all stages of maize growth and all above-ground plant structures, causing damage that leads to yield losses

in absence of control. According to Day *et al.*, (2017) yield losses on maize as a result of *S. frugiperda* damage for Southern African countries is expected to range between 2.481M and 6.187 M United States dollars. They also reduce the quality of maize making marketability difficult to many farmers. Integrated pest management options for controlling *S. frugiperda* have not been fully developed therefore synthetic chemicals are commonly used to control the pest due to their rapid knockdown effect.

Despite being fast acting, synthetic pesticides can harm beneficial organisms such as bees and also promote development of pest resistance and resurgence. Moreover, synthetic pesticides pose risks to human and health, causes environmental pollution and are often expensive for many smallholder farmers (Harrison *et al.*, 2019). Among a variety of remedial measures for fall armyworm management, are botanical pesticides. Use of botanical pesticides is one of sustainable agro-ecological option available. The botanicals including *Datura Stramonium* (thornapple), *A. indica*, *T. vogelii* and *Solanum nigrum* (black nightshade) have been used on both field pests and storage pests showing the pesticidal effect. Ahissou *et al.*, (2021) highlighted several plant species with pesticidal properties that are recognized by smallholder farmers. They are locally available and are cheaper and accessible compared to conventional pesticides (Bharathi *et al.*, 2026). Botanicals are effective at levels that may be harmless to mammals. Consumers are increasingly favoring organically produced foods over those grown with synthetic chemicals due to their perceived benefits including environmental sustainability, enhanced food safety and reduced chemical residues.

1.2 Problem Statement

Botanical pesticides such as *T. vogelii*, *A. indica* and *C. quadrangularis* have been reported as potential alternatives to synthetic pesticides their effectiveness under the environmental conditions of Natural Region IV has not been adequately established. Lack of locally generated information makes it difficult for farmers to select the control method. Therefore, there is need to evaluate the effectiveness of these botanicals for the control of fall armyworm in maize production in Natural Region IV of Zimbabwe.

1.3 Justification

The continued reliance on synthetic pesticides for controlling fall armyworm (*S. frugiperda*) is unsustainable due to high costs, rising pest resistance, and negative impacts on human and the environment. Botanical pesticides derived from *T. vogelii*, *A. indica* and *C. quadrangularis* may provide affordable, environmentally friendly for fall armyworm

management in maize fields. However, there is limited information comparing the effectiveness of these botanicals under local conditions. Therefore, this study is expected to generate information on the most effective botanical pesticides among *T. vogelii*, *A. indica*, and *C. quadrangularis* on the control of *S. frugiperda*. The findings may contribute to sustainable pest management, improved maize productivity and enhanced food security among smallholder farming communities.

1.4 Main Objectives

To determine the most effective crude aqueous leaf extract among *T. vogelii*, *A. indica* and *C. quadrangularis* for the control of *S. frugiperda* in maize production.

1.5 Specific Objectives

1. To determine the effect of botanical crude aqueous leaf extracts of *T. vogelii*, *A. indica* and *C. quadrangularis* on fall armyworm pest incidence in maize.
2. To determine the effect of botanical crude aqueous leaf extracts of *T. vogelii*, *A. indica* and *C. quadrangularis* on fall armyworm foliar damage in maize.
3. To determine the effect of aqueous leaf extracts of *T. vogelii*, *A. indica*, *C. quadrangularis* on maize plant height.
4. To determine the effect of botanical crude aqueous leaf extracts of *T. vogelii*, *A. indica* and *C. quadrangularis* on maize yield.

1.6 Hypotheses

Botanical crude aqueous leaf extract type has significant effect on fall armyworm pest incidence in maize.

Botanical crude aqueous leaf extract type has significant effect on fall armyworm foliar damage in maize.

Botanical crude aqueous leaf extract type has significant effect on maize plant height.

Botanical crude aqueous leaf extract type has significant effect on maize yield.

CHAPTER 2: LITERATURE REVIEW

2.1 Importance of Maize

Maize is a dominant staple crop in most west and central African including Zimbabwe. According to VIB, (2017) more than 300 million people in Africa depend on maize as their main food crop. In Zimbabwe survey results revealed that 1,819,819 MT of maize was produced during the 2024/2025 season (Development, 2025). Maize is a nutrient- rich crop that contains 10% protein, 3.5% crude fibre and 80% carbohydrates (Adiaha, 2017).The importance of maize extends beyond direct human consumption to its critical role in livestock rations, the green plant maybe cut before tasseling and used for foliage. In diet of man and livestock, maize provides a large amount of energy. According to FAO, (2023) 54%, 19%,13.8%, and 14% were used for feed, food manufacture, direct food and bioethanol respectively. In addition to its consumption as a whole grain, maize is widely processed into numerous indigenous foods, flours, gifts, starches, maize meals, sweeteners, cooking oil, breads, snacks, bioethanol and alcoholic beverages (Adiaha, 2017). Besides its importance as a food crop, maize has immense potential for job creation along its value chain which includes production, processing, marketing and distribution. The maize sector also supports the agro-industries that manufacture and supply agricultural inputs such as fertilizers, improved seed varieties and herbicides. These agro-industries also create create employment opportunities chemical manufacturing, seed production, packaging, transportation and distribution (Asfaw *et al.*, 2024). Despite its important, its production is severely affected by various factors.

2.2 Challenges in maize production

Maize production continues to face numerous constraints that hinder optional yields, threaten food security and limit the income of farmers. These problems are both socio-economic and environmental in nature. Some of the challenges in maize production includes poor soil fertility, climate variability and unreliable rainfall and lack of access to quality seeds remain a serious problem (Anyim *et al.*, 2020). Many smallholder farmers lack the knowledge or financial capacity to purchase certified seeds; they continue to use traditional seeds which are often low yielding and susceptible to diseases. Although improved hybrid and drought-

tolerant varieties are available, they are frequently unaffordable or difficult for most rural farmers to obtain (Ssemugenze *et al.*, 2024).

Moreover, limited access to markets, coupled with poor infrastructure, reduces profitability of maize farming. Many farmers lack timely information about market price and have little bargaining power, forcing them to sell at low prices (Asfaw *et al.*, 2024). Low market price also demotivates farmers, leading to decreased maize productivity in Zimbabwe.

Furthermore, maize production is heavily affected by pests and diseases causing significant yield losses. Major maize disease includes grey leaf spot (*Cercospora zea maydis*), maize streak virus and rust among others. They are several pests that also cause damage on maize but the major ones are lepidopteron insect for example the fall armyworm. The larvae feed on every part of maize that is on leaves, tassels, ears and tassels causing significant direct and indirect damage. *S. frugiperda* has become a major threat in recent years in sub-Saharan Africa (Prasanna, 2018).

In addition, significant post-harvest losses that occurs due to poor storage, poor drying techniques and storage pests is also a challenge in maize production especially in Zimbabwe. Maize is highly susceptible to mold growth, especially aflatoxin contamination, which not only possess serious health risks but also lowers its market quality and value. It is also affected by pests such as maize weevils, they affect grain in the field and in storage (Kambrekar *et al.*, 2022). The damage caused is irreversible and affects both farmers and traders. Food losses can be quantitative as measured by reduction in weight or volume, or qualitative, such as reduced nutrient value and unwanted changes in taste, colour, texture, or cosmetic features of food. According to Prasanna *et al.*, (2020) the concentrations of various nutrients in maize kernels depend on the genotype, interaction between genotype and environment, agronomic management and post-harvest handling.

2.3 Description and biology of fall armyworm (*S. frugiperda*)

Fall armyworm (*S. frugiperda*) is a polyphagous pest, which originated from tropical Americas. It is a highly destructive pest with a host range over 80 plant species causing massive economic losses (Anyim *et al.*, 2020). Fall armyworm belongs to the family Noctuidae and to the order Lepidoptera. The fall armyworms are stripped greyish-green caterpillars with dark-brown to black heads. *S. frugiperda* undergoes complete metamorphosis, meaning it passes through different developmental stages namely egg, larva,

pupa and adult moth. Life cycle can be completed in 30 days at an average daily temperature of 28 °(Prasanna, 2018).

S. frugiperda's rate of reproduction and multiplication is rapid for example, a single female moth can lay eggs between 1,000-2,000 during its lifetime showing the high fecundity of the pest (Matova *et al.*, 2020). Oviposition of creamy white eggs typically occurs at night on the underside of leaves near the base of the plant, close to the intersection of the leaf and stem (Togola *et al.*, 2025). The eggs are laid in egg masses of between 100-200 eggs and are covered in a protein sheath for protection against chemicals and natural enemies. Eggs hatch within 2-3 days in warmer climates (Hruska,2019).

The next stage on the life cycle is the larval stage which is the most destructive, threatening global food security. The larval stage undergo six instars which takes duration of 14 and 30 days in warmer summer and cooler winter months respectively (Togola *et al.*, 2025). The young larvae are light green with dark head. They change colour progressively from light green colour to dark brown gradually as they mature and they can reach lengths of 34 to 46 mm when fully grown. A feature used to distinguish mature larvae is an inverted “Y” shape on front of their heads, along with four prominent dots arranged in a square pattern on the dorsal side of their last abdominal segment (Matova *et al.*, 2020).

After completing the larvae stage the insect progress into the pupal stage. Pupae is reddish brown in colour and forms a cocoon of about 20-30mm in length and its oval in shape mostly found in the soil in 2-8cm deep (Sagar *et al.*, 2020). The pupal stage lasts 9-14 days, after which adults moths emerge. Adults moths have a life span of approximately 10 days (Matova *et al.*, 2020). The *S. frugiperda* adults are nocturnal in behavior, they are highly active at night seeking mates and expanding into new territories while staying elusive during the day (Togola *et al.*, 2025). Male moths display a distinct white spot near the tip of each forewing and more pronounced markings, whereas females are less body patterned and lack the white spot. The adult moths are migratory in nature and they can fly over long distance when conditions are favorable (Togola *et al.*, 2025)

2.4 Impact of fall armyworm (*S. frugiperda*) on Maize yield.

According to (Goergen *et al.*, 2016), fall armyworm was detected in West Africa, the first report outside of its native range of Americas in 2016. *Spodoptera frugiperda* is an invasive pest that is causing devastating effects on maize production and threatening the livelihoods of

millions of poor smallholders across sub-Saharan Africa and Asia (Tambo *et al.*, 2020). Day *et al.* (2017) reported that if *S. frugiperda* left uncontrolled in 12 main maize producing African countries it can cause yield losses which range from 8.3 to 20.6 million tonnes in a year. Baudron *et al.*, (2019) reported maize yield losses of 11.57% in Zimbabwe due to fall armyworm based on field scouting method for two districts.

Larval stage is the most destructive stage, young larvae hide in the funnel during the day and come out at the night to feed on leaves. Larvae feed aggressively on maize leaves, creating holes and windowing symptoms, which reduces photosynthesis and weakens plant growth (Chisonga *et al.*, 2023). In young plants stems maybe cut providing the evidence of the damage. Larvae can feed and damage the growing point, a symptom 'dead heart' which prevents any cobs from forming (Togola *et al.*, 2025). It can bore into the developing reproductive structures such as maize cobs reducing yield quality and quantity.

2.5 Strategies to control fall armyworm (*S. frugiperda*).

2.5.1 Cultural control

This method involves crop rotation, field sanitation practices, early planting and use of early maturing varieties to mitigate fall armyworm infestation (Cokola *et al.*, 2023). Timely and thorough field sanitation, removing crop residues after harvest and weeding reduces overwintering sites (Togola *et al.*, 2025). Using early maturing varieties allows maize ears to escape the higher fall armyworm densities that develop later in the season (Day *et al.*, 2017). Intercropping with minor attractant or repellent plants crop reduce damage to maize crop. According to Hailu *et al.* (2018) maize intercropped with leguminous crops of bean (*Phaseolus vulgaris*), soybean (*Glycine max*) and groundnut (*Vigna unguiculata*) significantly decreases fall armyworm attack by up to 40% compared to monocultured maize. In Zimbabwe some smallholder farmers rely on application of soils and wood ashes to leaf whorls as a way of controlling fall armyworm. Cultural control generally, reduce initial pest establishment mainly by disrupting the pest life cycle and lowering egg-laying sites.

2.5.2 Biological control

Togola *et al.*, (2025) reported that biological method is an effective strategy for managing fall army. According to Cock *et al.*, (2017) many indigenous natural enemies have been discovered, with up to 70% parasitism. A wide range of natural enemies such as parasitoids, predators, entomopathogenic fungi, viruses and bacteria reduces fall armyworm.

Entomopathogenic fungi for example *Beauveria bassiana* also control fall armyworm in maize crops. This method can be implemented through two primary approaches the argumentative biocontrol and inoculative biocontrol.

According to Banson *et al.*, (2020) the method involves the use of nucleopolyhedrovirus (NPV) which are naturally occurring viral disease for caterpillars. NPV can be applied via overhead irrigation. The NPV particles that are known polyhedral inclusion bodies (PIB) must be eaten by the larvae for infection to take place. Once the PIB is ingested even it is a single virus it circulates the whole body and is sufficient to kill the larvae within a period of 7 days. The method of NPV is highly specific and environmentally friendly, it should give good larvae control in silking maize if applied via ground rig fitted with droppers targeted at the cob and silk plant area.

2.5.3 Chemical control

Togola *et al.*, (2025) reported that most African farmers rely on the application of synthetic pesticides to control the fall armyworm (*S. frugiperda*). Several synthetic pesticides including carbaryl, chlorpyrifos, methomyl, diazinon and methyl parathion have been used in response to invasion of fall armyworm (Mukanga *et al.*, 2024). The use of insecticide to control fall armyworm should be done when egg masses are found more than 5% of plants, 25% of the plants have leaf damage or when 50% of the plants have severe leaf damage with live larvae still present. Excessive use of these chemicals leads to development of resistance, pest resurgence and harm to non-target organisms (Deshmukh *et al.*, 2020). However, the effects of chemicals to the environment and high cost has been a challenge to many smallholder farmers.

2.5.4 Integrated pest management

An integrated pest management approach is widely recommended as the most effective and sustainable strategy. The core strategy for effective fall armyworm control is to prevent, monitor and Act approach, which emphasizes crop resilience (Deshmukh *et al.*, 2020). It involves the combination of preventative, physical, biological, botanical and chemical method to achieve long term pest control while minimizing risks to human and environment. Chemical pesticides are only used when necessary, at recommended rates.

2.5.5 Botanical insecticides

The use of synthetic chemicals has associated problems hence the quest to seek sustainable alternatives including botanicals. Botanicals are various plant species that have insecticidal

properties (Siazemo and Simfukwe, 2020). They have diverse biological activities resulting in high mortality, extended larval duration, decreased pupa weight, antifeedant effects, growth inhibition and reduced fecundity (Deshmukh *et al.*, 2020). Plant insecticides have many advantages including being relatively cheap, less poisonous to both humans and animals and they do not harm natural enemies of the pests.

Several plant species have been tried for fall armyworm. Mukanga *et al.*, (2022) reported that crude aqueous leaf extracts resulted in more than 40% fall armyworm larvae mortality. In this study *T. vogelii*, *A. indica* and *C. quadrangularis* were selected for their insecticidal properties and broad availability in local environment. Their selection also stems from their accessibility to smallholder farmers who have limited financial resources.

2.5.5.1 Fish poison bean (*Tephrosia vogelii*) as a natural pest control agent

T. vogelii is mainly cultivated as fish poison bean. It is a herbaceous plant that belongs to the family of Leguminosae native to tropical Africa (Tlankka *et al.*, 2020). *T. vogelii* is a multiple function plant with fish toxicity, pesticidal and soil improving properties. It is known for its ability to deter pests on animals, as well as for its use in organic pesticides solutions for controlling soft-bodied pests. It was used by various workers who proved its efficacy on various animal parasites and crop pests. In Zimbabwe it is used to control ticks in dairy animals because it was found that there was no significant difference between *T. vogelii* and Triatix dip at 5% level (Muhoozi *et al.*, 2023).

T. vogelii possesses diverse bioactive chemical compounds including the chemotype 1(C1) which contain rotenoids which are mainly found in leaves, but are also present in varying proportion in other parts (Muhoozi *et al.*, 2023). According to Tlankka *et al.*, (2020) rotenoids differ in their effectiveness against pests, rotenone is the most active rotenoid compared to deguelin and tephrosin. Rotenone inhibits mitochondria during respiration and this inhibition causes cellular respiratory malfunction which stops energy generation leading to death (Moonde *et al.*, 2018). Alao and Adebayo, (2015) also reported the efficacy of *T. vogelii* in controlling field pests in watermelon. Furthermore, *T. vogelii* is also used in Zimbabwe and Malawi to protect stored maize against *Sitophilus ssp* (Muhoozi *et al.*, 2023). They also reported that treatments with more *T. vogelii* showed higher mortality percentage of against fall armyworm larvae compared to *A. indica*. Moreover, *T. vogelii* is promoted as an agroforestry tree due to its ability to fix nitrogen and as green manure, mulch and for

controlling soil erosion. When *T. vogelii* was grown alongside maize in Malawi it produced more acre than fertilized monoculture maize.

2.5.5.2 Neem (*Azadirachta indica*) as a natural pest control agent

A. indica is a promising candidate that has been used for years in agriculture. It offers an environmentally friendly, cost effective alternative to conventional pesticides. Okello *et al.*, (2024), reported that neem is known for its bio-insecticidal properties derived from compounds like Azadirachtin and nimbin. A number of researches point to Azadirachtin as the most important active ingredient capable of repelling, deterring insect feeding and inhibiting their growth and reproduction. The different parts of neem tree including leaves, barks, and roots can be used to produce pesticide, which is applied in various form such as neem powder, oil and extracts. In support of these findings (Okello *et al.*, 2024) also reported the insecticidal activity of neem extracts in controlling fall armyworm. In many African countries recent studies have reported appreciable results of different neem extracts against fall armyworm (Rioba and Stevenson, 2020). Siazemo and Simfukwe, (2020) reported the effectiveness of neem extracts in controlling the larvae population of fall armyworm causing 63% mortality.

2.5.5.3 Veldt grapes (*Cissus quadrangularis*) as a natural pest control agent

C. quadrangularis commonly referred to as veldt grape or devil's backbone, serves as a natural pest control solution that brings numerous advantages to agricultural practices. The plant's innate defensive chemicals make it a suitable choice for integrated pest management strategies, which aid in diminishing pest pressure on primary crops. Additionally, the use of *C. quadrangularis* aligns with sustainable farming techniques, as it is biodegradable, widely distributed in various tropical regions, and poses minimal risk to non-target organisms. According to Bharathi *et al.*, (2026) *C. quadrangularis* demonstrates notable larvicidal and wound healing activities supported by its rich composition of vitamin C, carotenoids and secondary metabolites. Green-synthesized silver nanoparticles derived from *C. quadrangularis* exhibited the highest toxicity against adult Togo Starburst (*Heteroscodra maculata*), followed by the aqueous extract and AgNO₃ solution.

CHAPTER 3: MATERIALS AND METHODS

3.1 RESEARCH SITE

The research was conducted at Murabwi Farm in Masvingo district of Masvingo Province, Zimbabwe. It is located at 20 ° 24 29 S and 30 °55 44 E. The area is under agro-ecological region IV, characterised by semi-arid conditions, receiving an average rainfall of 450-650mm per year and mean annual temperatures ranging from 19-22 °C. The site is situated at an altitude of about 924 meters above the sea level. The soils in the experimental field are predominantly loamy sandy, which is typically associated with rapid drainage, low water-holding capacity and low inherent fertility.

3.2 Experimental design

The experiment was laid in a Randomized Complete Block Design (RCBD) with five treatments replicated four times. The five treatments were evaluated, comprised of three crude botanical leaf extracts (*A. indica*, *T. vogelii* and *C. quadrangularis*), alongside a positive control (Lambda-Cyhalothrine) and negative(water). The experiment was divided into blocks based on soil type which served as the blocking factor.

3.3 General trial management

3.3.1 Land preparation and planting

The experimental site was cleared to remove weeds and crop residues. Primary tillage was conducted using ox-drawn plough. This was followed by harrow to break soil clods and produce fine tilth. The plots were measuring 5m × 3m with pathways of 1m width. The planting holes were made using a hoe. Maize was planted on 10 December 2025 at a spacing of 75cm inter-row and 20cm intra-row to give a plant population of 66,667 plants per hectare. The early-maturing maize variety SC 555, which takes about 135 days to reach maturity was used. The variety is known for its high yielding potential.

3.3.2 Fertilizer management

Compound D (7:14:7) was applied at a rate of 400kg per ha as a basal dressing during planting to provide nutrients for early crop establishment. Fertilizer was carefully covered with a thin layer of soil to prevent direct seed contact with fertilizer. Ammonium nitrate was subsequently applied as a top dressing at a total rate of 300kg/ha using the split application

method to enhance nitrogen use efficiency and reduce losses. The fertilizer was applied using the hill placement method adjacent to the plants, with the first application at two weeks after germination and second at six weeks after emergence, resulting in two split applications of 150kg/ha each.

3.3.4 Weed management

Timely manual weeding, was carried out at the third and sixth week after planting to effectively control weed infestation and minimize competition for nutrients, water and light. This practice ensured a relatively weed-free environment during the critical stages of crop growth, thereby promoting optimal maize development and improving overall productivity.

3.4 Preparation and application of the treatments

Fresh leaves of *T. vogelii*, *A. indica*, and *C. quadrangularis* were collected and washed thoroughly using tapped water to remove dust. *Tephrosia* leaves were pounded using a pestle and mortar, measured into 220g and soaked in 1 litre of water. The mixtures were thoroughly stirred and left to settle for 24 hours. Mutton cloth was used to filter residue before spraying. 220g *A. indica* and 220g *C. quadrangularis* were processed using the same procedures as for *T. vogelii*. Table 3.1 below shows the different treatments and their concentrations or application rate.

Table 3.1: Different treatments and their concentrations

Treatment	Concentration (mass/ volume of water)
<i>Tephrosia vogelii</i>	220 g/L
<i>Azadirachta indica</i>	220 g/L
<i>Cissus quadrangularis</i>	220 g/L
Lambda-Cyhalothrin 50EC	0.2 ml/L
Plain tape water (control)	1 L

3.5 Spraying and sampling

Natural infestation by fall armyworm (*S. frugiperda*) was observed three weeks after planting. From the 5th week after planting, spraying began and it was done at weekly intervals for four weeks. The prepared concentrations were applied without further dilution using a knapsack sprayer. Lambda-cyhalothrine was applied as per manufacturer's instructions label.

Plain water was used as a control to show the effect of water used in spraying other treatments.

3.6 Data collection

3.6.1 Pest incidence

Pest incidence was determined by counting the number of plants infested with fall armyworm larvae out of ten sampled plants per plot. The incidence was expressed as a percentage using the formula:

$$\text{Pest incidence} = \frac{\text{Number of infested plants}}{\text{Total number of plants assessed}} \times 100$$

3.6.2 Leaf damage

This involved scoring the leaf damage using the scale of 0-9 ,visual rating described by Chisonga *et al.*, (2023). Ten selected sample plants were assigned a score ranging from 0 (no damage) to 9 (severe leaf damage), based on the extent of feeding injury observed, in accordance with standard descriptions provided in Table 3.2. Lastly the average damage score per plot was then calculated.

Table 3.2: Davis Scale for Leaf Damage

Score	Description
0	No visible leaf damage
1	Pinholes or small lesions on leaves
2	Small shot holes, minor feeding damage
3	Several shot holes; small elongated lesions
4	Elongated lesions up to 2.5 cm; moderate feeding
5	Elongated lesions > 2.5 cm; noticeable defoliation
6	Large lesions; significant leaf feeding ; whorl damage visible
7	Heavy feeding; most leaves with large lesions; whorl severely damaged
8	Severe defoliation; most leaf tissue destroyed except midrib
9	Almost complete plant destruction or dead heart

3.6.3 Plant height

Plant height was measured in centimetres from the base of the plant at ground level to the tip of the tallest leaf using measuring tape. The mean plant height per plot was calculated from the sampled plants.

3.6.4 Yield

It was obtained by harvesting and drying cobs from 10 tagged plant per plot at approximately 14% moisture content. The dried cobs were shelled and the grain was carefully weighed using a 10kg digital kitchen scale and average weight of each treatment was obtained.

3.7 Data analysis

The data on pest incidence, leaf damage, plant height and yield were subjected to Analysis of Variance (ANOVA) using GenStat version 18 statistical package. Where there were significant differences among the means, comparison was done using the Least Significance Difference (LSD), at 5% significance level.

CHAPTER 4: RESULTS

4.1 Effect of different crude aqueous botanical leaf extracts on fall armyworm incidence in maize

There was highly significant difference ($p < 0.001$) in the fall armyworm incidence among the treatments across the 4 sampling intervals (weeks 5, 6, 7 and 8 after planting). The highest pest incidence was recorded in the negative control treatments and lowest mean was recorded in Lambda-Cyhalothrin treatments (Table 4.1).

Table 4.1: Effect of different crude aqueous botanical leaf extracts on fall armyworm incidence in maize

Treatment	Pest incidence at 5 weeks	Pest incidence at 6 weeks	Pest incidence at 7 weeks	Pest incidence at 8 weeks
<i>Tephrosia vogelii</i>	35.0 ^b	40.0 ^{bc}	47.50 ^c	60.00 ^b
<i>Azadirachta indica</i>	27.5 ^c	35.0 ^{cd}	45.00 ^{cd}	55.00 ^c
<i>Cissus quadrangularis</i>	35.0 ^b	45.0 ^b	55.00 ^b	62.50 ^b
Lambda-Cyhalothrin	22.5 ^c	30.0 ^d	40.00 ^d	50.00 ^d
Water	52.5 ^a	65.0 ^a	72.50 ^a	80.00 ^a
Grand mean	34.5	43.0	52.00	61.50
LSD	7.03	8.89	5.447	4.872
P Value	<0.001	<0.001	<0.001	<0.001
CV%	13.2	13.4	6.8	5.1

Treatment means followed by the same superscript are not significantly different at $p \leq 0.05$.

4.2 Effect of different crude aqueous botanical leaf extracts on maize leaf damage

There was significant difference ($p < 0.05$) in the maize leaf damage among the treatments at 5 weeks after planting sampling period. There was highly significant difference ($p < 0.001$) in the maize leaf damage among the treatments across the other sampling intervals (weeks 6, 7 and 8 after planting). The negative control had the highest mean leaf damage score and lowest in Lambda-Cyhalothrin. The damage caused by *S. frugiperda* was mild or minimal on maize plants across the treatments, except the control treatment. *A. indica* and Lambda-Cyhalothrin recorded the lowest mean leaf damage score whilst negative control recorded the highest leaf damage (Table 4.2)

Table 1.2: Effect of different crude aqueous botanical leaf extracts on maize leaf damage

Treatment	Leaf damage at 5 weeks	Leaf damage at 6 weeks	Leaf damage at 7 weeks	Leaf damage at 8 weeks
<i>Tephrosia vogelii</i>	3.000 ^b	3.50 ^{bc}	4.25 ^b	5.250 ^b
<i>Azadirachta indica</i>	2.750 ^{bc}	3.25 ^{bc}	4.00 ^b	4.250 ^c
<i>Cissus quadrangularis</i>	3.000 ^b	4.00 ^b	4.50 ^b	5.000 ^b
Lambda-Cyhalothrin	2.500 ^c	3.00 ^c	3.75 ^b	4.750 ^{bc}
Water	3.750 ^a	5.25 ^a	6.25 ^a	7.000 ^a
Grand mean	3.000	3.80	4.55	5.250
LSD	0.5071	0.855	0.783	0.5799
P Value	0.002	<0.001	<0.001	<0.001
CV%	11.0	14.6	11.2	7.2

Treatment means followed by the same superscript are not significantly different at $p \leq 0.05$

4.3 Effect of different crude aqueous botanical leaf extracts on maize plant height

There was highly significant difference ($p < 0.001$) in maize plant height among the different treatments. The highest mean height of 140cm was recorded on Lambda-Cyhalothrin and the lowest mean height of 131cm was recorded on negative control (water) treatments (Table 4.3).

Table 4.3: Effect of different crude aqueous botanical leaf extracts on maize plant height

Treatment	Plant height at 5 weeks	Plant height at 6 weeks	Plant height at 7 weeks	Plant height at 8 weeks
<i>Tephrosia vogelii</i>	61.75 ^c	84.50 ^c	109.00 ^c	134.25 ^c
<i>Azadirachta indica</i>	63.50 ^b	87.00 ^b	111.75 ^b	137.00 ^b
<i>Cissus quadrangularis</i>	62.0 ^{bc}	84.75 ^c	109.00 ^c	133.25 ^c
Lambda-Cyhalothrin	65.75 ^a	90.50 ^a	114.00 ^a	140.00 ^a
Water	57.25 ^d	80.00 ^d	105.25 ^d	131.00 ^d
Grand mean	62.05	85.35	109.80	135.10
LSD	1.585	1.676	1.585	2.014
P Value	<0.001	<0.001	<0.001	<0.001
CV %	1.7	1.3	0.9	1.0

Treatment means followed by the same superscript are not significantly different at $p \leq 0.05$

4.4 Effect of different crude aqueous botanical leaf extracts on maize yield

There was highly significant difference ($p < 0.001$) in maize grain yield among the different treatments. The highest grain yield and lowest total grain yields were recorded in Lambda-Cyhalothrin and negative control, respectively (Figure 4.1).

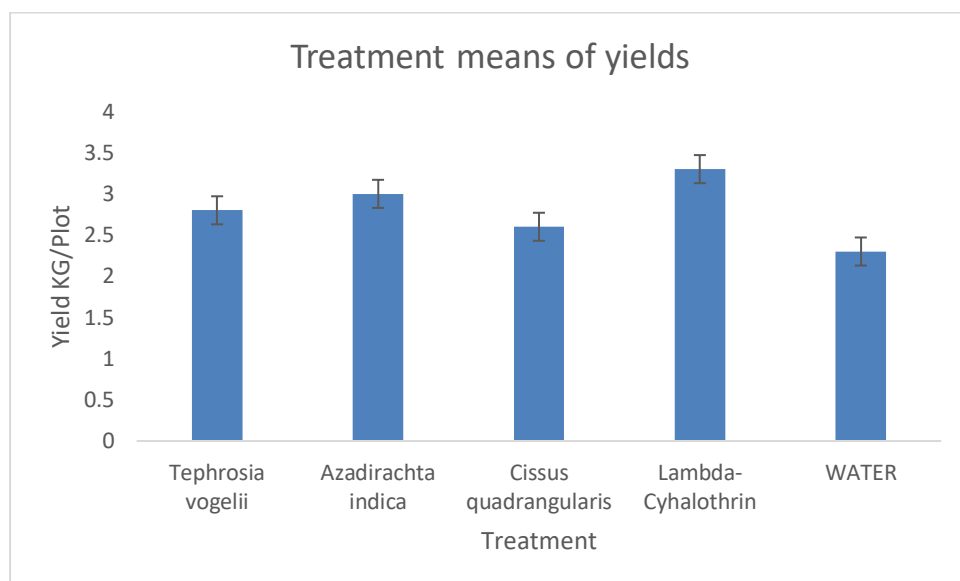


Figure 4.1: Effect of different crude aqueous botanical leaf extracts on maize grain yield

CHAPTER 5: DISCUSSION

5.1 Effect of different crude aqueous botanical leaf extracts on fall armyworm incidence in maize

There was highly significant difference ($p < 0.001$) in fall armyworm incidence among the treatments in all time periods (weeks 5, 6, 7, 8). Lambda-Cyhalothrin was the most effective, consistently recorded the lowest incidence than negative control (water) recorded the highest incidence throughout the sampling. The results supported the work of Sisay *et al.*, (2019), who observed that synthetic insecticides significantly reduced fall armyworm infestation in maize. Harrison *et al.* (2019) also reported effective suppression of fall armyworm populations using Lambda-Cyhalothrin under field conditions. This could be attributed to the rapid knockdown effect. Lambda Cyhalothrin acts by disrupting sodium channels in the insect nervous system, causing paralysis and eventual death of larvae. Even though Lambda-Cyhalothrin was the most effective the difference between Lambda-Cyhalothrin and *A. indica* was minor.

Amongst the botanical treatments that was used to control fall armyworm *A. indica* was most effective as compared to *T. vogelii* and *C. quadrangularis* and negative control. The results linked to the results of Sisay *et al.*, (2019) who reported that *A. indica* have high larval mortality compared to other plant botanicals. Prasanna *et al.*, (2018) also observed that neem-based products effectively reduced infestation and feeding activity of *S. frugiperda*. The performance of Neem leaf extract may be due to its multiple modes of action as it acts as a repellent, antifeedants, insect growth regulator, and attractant. It also contains *Azidarachtin* to suffocate insects, hence leading to their death Okello *et al.*, (2025).

Lower pest incidence recorded in *T. vogelii* may be due to the presence of retene ($C_{23}H_{22}O_6$) is a selective, non-specific and non-systemic chemical which is both a contact and stomach poison to insects Zhang *et al.*, (2020). It kills the pests slowly by stopping them from feeding almost immediately and exerts its toxic action. Phambala and Stevenson.,(2020) also noted that pesticidal plants possess strong insecticidal properties against lepidopteran pests.

C. quadrangularis recorded the lowest highest pest incidence on botanicals but it was better compared to control. *C. quadrangularis* contains variety of phytochemicals these include alkanoids, flavonoids and phenolics that are responsible for its insecticidal effects, such as

larvicidal, antifeedants, repellent, and growth-inhibitory effects Bharathi *et al.*,(2026). The poor efficacy poor could be related to the extraction method used. Crude aqueous extracts often extract fewer bioactive compounds compared to organic solvent extracts. Similar findings were also reported by Phambala and Stevenson.,(2020), who noted that some pesticidal plants show low mortality against fall armyworm because of difference in extraction methods.

5.2 Effect of different crude aqueous botanical leaf extracts on maize leaf damage

The results showed that there was significant difference ($p < 0.002$) among the treatments at 5WAP. From 6 weeks up to 8 weeks there was highly significant difference ($P < 0.001$). The treatments showed significantly lower leaf damage compared to the untreated plots. Results suggest a high potential of the treatments in controlling fall armyworm in maize fields in terms of level of leaf damage. Lambda-Cyhalothrin recorded the lowest leaf damage, were able to provide good crop protection against the *S. frugiperda* and this resulted in higher yields. These results agrees with the findings of Mukanga *et al.*, (2022) who also reported that Lambda- Cyhalothrin . On botanicals Neem recorded lower leaf damage this could be due to the presence of Azidarachtin to suffocate the fall armyworm, hence leading to their death. Comparable findings were reported by Sisay *et al.* (2019), who noted diminished fall armyworm leaf damage in maize treated with neem-based botanicals. *A. indica* produced better results than *T. vogelii*. This is in agreement with the findings of Moonde *et al.*, (2018), who reported that treatments containing higher concentrations of *T.vogelii* resulted in greater mortality percentages of fall armyworm larvae compared to *A. indica*. The variation in results may be attributed to differences in environmental conditions. *T. vogelii* and *C. quadrangularis* showed slight difference on their effect of leaf damage. This may be due to the environmental factors such as rainfall, temperature, sunlight and degradation of the extracts after application Mukanga *et al.*, (2022). Retonoids mainly act through contact toxicity and may not possess strong insect growth regulatory properties like neem.

5.3 Effect of different crude aqueous botanical leaf extracts on maize plant height

The results showed significant differences among treatments on maize plant height at all sampling periods ($p < 0.001$). Lambda-Cyhalothrin and *A. indica* produced taller plants

compared to untreated control this may be associated with reduced pest pressure and improved plant vigor. Greater plant height recorded under Lambda-Cyhalothrin treatment indicates that effective suppression of larvae allowed maize plants to utilize nutrients and photosynthates efficiently for vegetative growth. Similar results was reported by Mukanga *et al.*, (2022) who reported that synthetic pesticides reduced high percentage of leaf damage which reduces height of the plant.

The improved plant height under *A. indica* treatment may have been resulted from reduced feeding and protection of photosynthetic tissues. Mukanga *et al.*, (2022) similarly reported that *A. indica* effectively reduced fall armyworm damage thereby promoting better maize growth and improved plant vigor.

The shorter plants observed in the untreated control could be attributed to severe fall armyworm infestation and extensive leaf damage which reduced photosynthetic efficiency. The results linked to the findings of Hruska., (2019) who reported stunted maize growth in heavily infested fall armyworm fields.

5.4 Effect of different crude aqueous botanical leaf extracts on maize grain yield

The results showed significant differences among treatments on maize yield with Lambda-Cyhalothrin recording the highest yield of 3.3 kg per 10 cobs per plot followed by *A. indica* (3.0 kg per 10 cobs per plot), *T. vogelii* (2.8 kg per 10 cobs per plot) and *C. quadrangularis* (2.6 kg per 10 cobs per plot), while negative control recorded the lowest yield of 2.3 kg per 10 cobs per plot. The higher yields obtained under treated plots may have been due to effective reduction of fall armyworm infestation and leaf damage which improved photosynthetic efficiency and grain filling. The superior performance of Lambda-Cyhalothrin could be attributed to rapid knockdown effect and residual insecticidal effects against fall armyworm larvae. This finding agrees with Sisay *et al.*, (2019) who reported that synthetic insecticides significantly increase grain yield through suppression of fall armyworm populations. Similar observations were made by Prasanna *et al.*, (2018) who found that effective chemical control fall armyworm increased maize productivity under field conditions.

Although Lambda-Cyhalothrin recorded the highest yield its advantage over *A. indica* was minimal. The increased yield observed under *A. indica* treatment may have resulted from

presence of azadirachtin which possess antifeedants, repellent and insect growth regulatory properties that reduce feeding damage and protect photosynthesis tissues. These findings are in agreement with Tembo *et al.*, (2018) who suggest that using extracts of pesticidal plant to control pests can be as effective as synthetic insecticides in terms of crop yields.

Although *T. vogelii* and *C. quadrangularis* produced lower yields compared to Lambda-Cyhalothrin and *A. indica*, they are still better compared with negative treatment indicating their potential in fall armyworm management. The insecticidal activity of *T. vogelii* may be linked to rotenoids which reduce insect feeding and survival. These findings agree with Steven *et al.*, (2012) who reported that *T. vogelii* possesses pesticidal capable of suppressing insect pests in crops.

The relatively improved yield under *C. quadrangularis* treatment may have been due to the presence of phytochemicals such as flavonoids and phenolics with insecticidal and antifeedants properties. Similar observations were reported by Bharathi *et al.*, (2026) who found that *C. quadrangularis* contains bioactive compounds effective against insect pests. The lowest yield was recorded in negative control due to severe fall armyworm infestation caused extensive leaf damage and reduced photosynthetic activity. The results are linked to the findings of Day *et al.*, (2017) who highlighted that uncontrolled fall armyworm infestations result in significant maize yield losses.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The study demonstrated that crude aqueous leaf extracts of *A. indica*, *T. vogelii* and *C. quadrangularis* were effective in reducing fall armyworm infestation, leaf damage and improving maize growth and yield compared to untreated control. Significant differences were observed among treatments among treatments for pest incidence, leaf damage, plant height and yield. Lambda-Cyhalothrin recorded the highest yield however, the difference between Lambda-Cyhalothrin and *A. indica* was relatively small, indicating that neem extract was nearly as effective as the synthetic insecticide in controlling fall armyworm and protecting maize productivity. *A. indica* proved to be the most effective botanical extract among the tested botanicals. Neem-treated plots consistently recorded lower pest incidence, reduced leaf damage, improved plant growth and higher yield compared to *T. vogelii* and *C. quadrangularis*.

Therefore, the study concludes that *A. indica* is the most effective botanical extract for the management of fall armyworm. Its use can help farmers reduce dependence on expensive synthetic insecticides while promoting safer, affordable and sustainable maize production.

6.2 Recommendations

Farmers should therefore adopt neem leaf extracts as an alternative to synthetic insecticides because it effectively reduced pest incidence and leaf damage while producing yields that were comparable to those obtained under Lambda-Cyhalothrin treatment. The use of neem can help resource-constrained farmers mostly the smallholder reduces production costs associated with expensive synthetic pesticides while promoting environmentally friendly and sustainable crop protection.

Farmers are also encouraged to integrate neem extracts with other integrated pest management practices such as early scouting, crop rotation, timely planting and field sanitation for improved fall armyworm control. Agricultural extension officers should train farmers on the proper preparation, extraction and application of neem-based pesticides to enhance effectiveness and adoption at farm level.

Further research should be done to determine application frequencies and storage conditions of *A. indica* extracts for maximum effectiveness against fall armyworm under different environmental conditions.

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APPENDICES

Summary of analysis of variance

Appendix 1: Variate: Pest_incidence_at_5_week

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum 3		175.00	58.33	2.80	
Block. *Units* stratum					
Treatment	4	2070.00	517.50		24.84 <.001
Residual	12	250.00	20.83		
Total	19	2495.00			

Appendix 2: Variate: Pest_incidence_at_6_weeks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum 3		100.00	33.33	1.00	
Block.*Units* stratum					
Treatment	4	2920.00	730.00		21.90 <.001
Residual	12	400.00	33.33		
Total	19	3420.00			

Appendix: 3: Variate: Pest_incidence_at_7_weeks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum 3		200.00	66.67	5.33	
Block.*Units* stratum					
Treatment	4	2570.00	642.50		51.40 <.001

Residual	12	150.00	12.50
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Total	19	2920.00
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Appendix 4: Variate: Pest_incidence_at_8_weeks

Source of variation	d.f.	s.s.	m.s.	v.r.	F	pr.
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Block stratum 3		55.00	18.33	1.83		
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Block.*Units* stratum						
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Treatment	4	2080.00	520.00		52.00	<.001
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Residual	12	120.00	10.00			
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Total	19	2255.00
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Appendix 5: Variate: Leaf_damage_at_5_weeks

Source of variation	d.f.	s.s.	m.s.	v.r.	F	pr.
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Block stratum 3		1.2000	0.4000		3.69	
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Block. *Units* stratum						
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Treatment	4	3.5000	0.8750		8.08	0.002
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Residual	12	1.3000	0.1083			
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Total	19	6.0000
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Appendix: 6: Variate: Leaf_damage_at_6_weeks

Source of variation	d.f.	s.s.	m.s.	v.r.	F	pr.
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Block stratum 3		2.8000	0.9333		3.03	
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Block. *Units* stratum						
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Treatment	4	12.7000	3.1750		10.30	<.001
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Residual	12	3.7000	0.3083			
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Total	19	19.2000
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Appendix: 7: Variate: Leaf_damage_at_7_weeks

Source of variation	d.f.	s.s.	m.s.	v.r.	F	pr.
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Block stratum 3	4.1500	1.3833	5.35	
Block. *Units* stratum				
Treatment	4	15.7000	3.9250	15.19 <.001
Residual	12	3.1000	0.2583	
Total	19	22.9500		

Appendix: 8: Variate: Leaf_damage_at_8_weeks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum 3	2.5500	0.8500	6.00		
Block.*Units* stratum					
Treatment	4	17.5000	4.3750	30.88	<.001
Residual	12	1.7000	0.1417		
Total	19	21.7500			

Appendix: 9: Variate: Plant_height_at_5_weeks_cm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum 3	26.550	8.850	8.36		
Block.*Units* stratum					
Treatment	4	155.700	38.925	36.78	<.001
Residual	12	12.700	1.058		
Total	19	194.950			

Appendix :10: Variate: Plant_height_at_6_weeks_cm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum 3	10.550	3.517	2.97		
Block.*Units* stratum					
Treatment	4	235.800	58.950	49.82	<.001
Residual	12	14.200	1.183		

Total 19 260.550

Appendix :11: Variate: Pant_heightat_7_weeks_cm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
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Block stratum3	6.800	2.267	2.14		
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Block.*Units* stratum

Treatment	4	173.700	43.425	41.03	<.001
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Residual	12	12.700	1.058		
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Total 19 193.200

Appendix: 12: Variate: Plant_height_at_8_weeks_cm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
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Block stratum3	13.000	4.333	2.54		
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Block.*Units* stratum

Treatment	4	194.300	48.575	28.43	<.001
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Residual	12	20.500	1.708		
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Total 19 227.800

Appendix: 13: Variate: Yield_kg_plot

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
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Block stratum3	0.12200	0.04067	2.24		
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Block. *Units* stratum

Treatment	4	2.45800	0.61450	33.83	<.001
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Residual	12	0.21800	0.01817		
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Total 19 2.79800

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