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MANAGEMENT OF THE FALL ARMYWORM (*Spodoptera frugiperda* J. E. SMITH) ON MAIZE IN SEKE DISTRICT, MASHONALAND EAST PROVINCE OF ZIMBABWE

BY

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Abstract

The Fall Armyworm, *Spodoptera frugiperda* (J. E. Smith) (FAW) is serious pest of maize and other cereals. A field trial was conducted at Mangwiro farm in the Beatrice Area of Seke district to evaluate the response of three maize varieties and chemical treatments in the control of FAW. The three maize varieties used were; SC513, SC529 and PAN53. There were three chemical treatments namely; Ecoterex, lambda cyhalothrin and Cabaryl. The fourth treatment was an untreated control. Each treatment was replicated three times. The trial was set up as a 3X4 factorial experiment with three varieties and three chemical treatments. Each treatment plot had four lines which were three meters long and replicated three times. The total number of plots was thirty-six. Inter-row spacing was 0.90cm and in row spacing was 0.20cm within the plots. Inter-row between blocks was 1.5m and inter-row within the block was 1m. Data on effect of chemical treatments on mean number of larvae per plot at 7, 8, 9, 10 and 11 weeks after planting (WAP) was collected. Data was also collected on the mean number of days to maturity for three varieties, mean leaf size, mean plant height, mean total number of leaves, plant vigor at maturity, mean plant biomass, mean cob quality scores, mean cob size (cm) and mean grain weight (tons/Ha).There were no significant differences ($p>0.05$) for the mean insect larvae numbers among the four treatments and between the three varieties at 7 WAP. There was a significant difference ($p<0.05$) in the mean insect larvae numbers among the four treatments at 8 WAP. The Ecoterex and lambda chemical treatments had significantly lower mean insect larvae numbers but were not significantly different from each other. There was a significant difference ($p<0.05$) in the mean insect numbers among the four treatments at 10 and 11 WAP. The Ecoterex and lambda treatments had significantly lower mean insect numbers but were not significantly different from each other at 10 WAP. There were significant differences ($P<0.05$) in the number of days to maturity across the three varieties. Variety SC513 had the lowest mean number of days to maturity and this was significantly different from variety SC529 which had a mean number of 135 days to maturity. There was no significant difference in grain yield across the three varieties and this was predominantly because the varieties are in the same medium maturity category. Overall, farmers are advised to use Ecoterex and lambda cyhalothrin in the control of FAW and this should preferably be done in a rotation to avoid the development of resistance in FAW to the insecticides.

Key words: *Spodoptera frugiperda* maize, Ecoterex, lambda cyhalothrin, Cabaryl.

Declaration Page

I declare that this dissertation is my original work except where sources have been cited and acknowledged. The work has never been submitted, or will it ever be submitted to another University for the award of a degree

Mafararikwa Reyai

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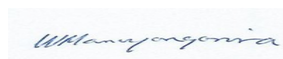
Walter Manyangarirwa  12/04/2021

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Main Supervisor's Full Name Main Supervisor's Signature (Date)

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Dedication

This work is dedicated to my beloved sons and supportive family.

Acknowledgements

I would like to thank my Uncle and my family for being my pillars of strength and for guiding me through university life. A special thank you goes to Mr. and Mrs. Mangwiro, Mr. C. Chikanda, Mr. T. Mpofu (AU farm manager), Dr. W. Manyangarirwa, Mr. T. Mtaita and the entire staff in the College of Health, Agriculture and Natural Resources for allowing me to carry this scientific research. I would like to acknowledge the Seed Co Company and Pioneer Seed Company for the opportunity to conduct my research and for the exposure to the field agricultural research. Finally, to my academic supervisor much gratitude is extended for the guidance that was provided in writing this research project.

All glory is to God.

List of Acronyms and Abbreviations

AAW	African armyworm.
AGRITEX	Agricultural, Technical and Extension Services of Zimbabwe.
AIMS	The Agricultural Information Management Standards Portal of the Food and Agricultural Organization of the United Nations (FAO).
ANOVA	Analysis of Variance.
BCAs	Biological Control Agents.
Bt	*Bacillus thuringiensis*.
CABI	Centre for Agriculture and Biosciences International.
EPA	Environmental Protection Agency.
FAO	Food and Agriculture Organization of the United Nations.
FAW	Fall armyworm.
GAP	Good Agronomic Practices.
GMOs	Genetically Modified Organisms.
IGC	International Grains Council.
IPM	Integrated Pest Management Practices.
NPPOs	National Plant Protection Organizations.
NPV	Nucleopolyhedrosis Virus.
PPT	Push –Pull Technology.
RUE	Resource Use Efficiency.
SfMNPV	*Spodoptera frugiperda* Multicapsid Nucleopolyhedrosis Virus.
USAID	United States Agency for International Development.

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CHAPTER 1 INTRODUCTION

1.1 Introduction

The Fall Armyworm, *Spodoptera frugiperda* (J. E. Smith) (FAW) is migratory in its native areas of Northern and Southern America. Its name is derived from its comportment during the 'fall', the season following autumn. The pest is known to cause extensive losses in corn, sorghum and forage (Sparks, 1979). It was first detected in Africa on the Island nation of Sao Tome and Principe in 2016, then later followed by spontaneous outbreaks in the Western African countries of Ghana (CABI, 2017), Nigeria, Benin and Togo reported in 2016 (Goergen *et al*., 2016; Rodney *et al*., 2018). As of 2017, fall armyworm was present throughout most of sub-Saharan Africa (FAO, 2017). In Africa, the pest has increasingly tended to become invasive, often seen to displace other key pests of maize, which has remained as the most important host plant. The first report of fall armyworm in Zimbabwe was in 2016 from Bubi district in Matabeleland North according to the Department of Agricultural, Technical and Extension Services of Zimbabwe (AGRITEX). The invasion caused huge public euphoria considering available information that showed its continued destruction of maize in Zimbabwe.

Maize (*Zea mays*, referred to as corn in North America) originated in central Mexico in around 5 000 BC. The crop was introduced to Europe in the sixteenth century, from where it spread to Africa and Asia. It is now one of the most widely-grown crops around the world in both temperate and tropical regions. It is among the 10 most important world crops by value according to (FAO). According to the FAO, world maize production in 2012 was over 870 million thousand tons, grown on 158 million hectares of land. Sources such as the FAO's Agricultural Market Information System (AIMS) and The International Grains Council (IGC) have forecasted maize production increasing to as high as 990 million thousand tons in 2014-2015 grown on almost 200 million hectares.

1.2 Background to the study

The Fall armyworm (FAW) (*Spodoptera frugiperda*) was first reported to be present in Africa in 2016. Since then, it has become a very destructive invasive pest in sub-Saharan Africa. Its main impact is on maize crops, which it attacks: it affects the crop at different stages of growth, from early vegetative stages to physiological maturity. It can cut down young plants and can also damage leaves, giving them a ragged, torn appearance. The pest feeds inside whorls and can destroy silks and developing tassels. FAW can also feed on developing kernels, which can reduce yields through direct losses, exposure of cobs to secondary infection and loss of grain quality and quantity. In several countries in Africa affected by FAW attack, farmer responses are predominantly based on the use of chemical pesticides. It is therefore important first to ensure the safe use of such pesticides by farmers, but also to promote and deploy against FAW. An integrated pest management (IPM) package made up of proven, sustainable and available technologies. Such a package should include: effective monitoring, scouting and surveillance; timely and need-based application of environmentally safer and low-risk synthetic pesticides and bio-rationals. Conservation of indigenous natural enemies, classical biological control; deployment of cultivars with tolerance or resistance. Promotion of low-cost agronomic practices cultural control and habitat management strategies, including push-pull technology (Capinera, 2000).

The fall armyworm's life cycle is completed within 30 days during summer, and 60 days during the spring and autumn seasons; during the winter, these caterpillars' life cycle lasts about 80 to 90 days, The number of generations a moth will have in a year varies based on climate, but in her life span a female will typically lay about 1,500 eggs. Because larva cannot enter into diapauses they cannot survive cold temperatures, (Luginbill, 1928).

Eggs are pale green or white at the beginning, get covered in scales, and turn clear brown to brown before hatching. They hatch within 2-3 days. There are 6 larval stages. Young larvae are pale colored. They become brown to pale green, and then turn darker at the latest stages. The larval stage lasts 12 to 20 days depending on ambient temperature and other environmental conditions. The larvae are generally characterized by 3 yellow stripes on the back, followed by a black, then a yellow stripe on the side. There are four dark spots forming a square on the second to last segment. Each spot has a short bristle. The head is dark shows a typical upside down Y-shaped pale marking on the front. The pupa is dark brown and hides in the soil, more rarely in the stalk. Pupa lives 12-14 days before an adult emerges. The moth is 3 to 4 cm wide. Its front wings are dark brown while the rear wings are grey white. It will live 2 to 3 weeks before dying. The larval stages are the ones that reach the protective region of the whorl, where it does the most damage, resulting in ragged holes in the leaves. Feeding on young plants can kill the growing point resulting in no new leaves or cobs developing. Often only 1 or 2 caterpillars are found in each whorl, as they become cannibalistic when larger and will eat each other to reduce competition for food. Large quantities of frass are present and are a sign of feeding damage. When the frass dries it resembles sawdust. If the plant is older and has already developed cobs, then the caterpillar will eat its way through the protective leaf bracts into the side of the cob where it begins to feed on the developing kernels.

After hatching the young caterpillars feed superficially, usually on the undersides of leaves. Feeding results in semitransparent patches on the leaves called windows. Young caterpillars can spin silken threads which catch the wind and transport the caterpillars to a new plant. The leaf whorl is preferred in young plants, whereas the leaves around the cob silks are attractive in older plants. Feeding is more active during the night. A clutch of 100-200 eggs are generally laid on the underside of the leaves typically near the base of the plant, close to the junction of the leaf and the stem. These are covered in protective scales rubbed off from the moths' abdomen after laying. When populations are high then the eggs may be laid higher up the plants or on nearby vegetation. Under warm conditions, a female moth can lay 6 to 10 egg masses of 100 to 300 eggs each, giving a maximum of 1 500 to 2 000 eggs in her lifetime of 2-3 weeks.

1.3 Statement of the problem

The problem was centered on farmers experiencing low yields and poor quality maize due to outbreak of FAW and its destructive feeding habits on maize crop. Fall armyworm (FAW) (*Spodoptera frugiperda*) was first reported to be present in Africa in 2016. Since then, it has become a very destructive invasive pest in sub-Saharan

Africa. Its main impact is on maize crops, which it attacks: it affects the crop at different stages of growth, from early vegetative to physiological maturity. It can cut down young plants and can also damage leaves, giving them a ragged, torn appearance. The pest feeds inside whorls and can destroy silks and developing tassels. FAW can also feed on developing kernels, which can reduce yields through direct losses, exposure of cobs to secondary infection and loss of grain quality and quantity. In several countries in Africa affected by FAW, farmer responses are predominantly based on the use of chemical pesticides. It is therefore important first to ensure the safe use of such pesticides by farmers, but also, at the same time, to promote and deploy against FAW an integrated pest management (IPM) package made up of proven, sustainable and available technologies. Such a package should include: effective monitoring, scouting and surveillance; timely and need-based application of environmentally safer and low-risk synthetic pesticides and bio-rationals; conservation of indigenous natural enemies and classical biological control; deployment of cultivars with tolerance or resistance; promotion of low-cost agronomic practices cultural control; and habitat management strategies, including push-pull technology. The Push-pull technology is an innovation from ICIPE.Its a pest management approach that uses repellent intercrops and attractive trap plant. Pests are repelled from the food crop and attracted to a trap crop simultaneously. The current trial was set up with a twin objective of evaluating the response of three maize varieties to FAW attack as well as to evaluate the effect of three insecticides on the incidence and severity of FAW damage.

1.4 Research Objectives

1.4.1 The Major objective

The overall objective of the research was to determine the effect and use of chemicals on FAW on productivity on three maize varieties.

1.4.2 Specific objectives were to;

a) determine the response of three maize varieties productivity to FAW attack.
b) determine the effectiveness of three chemicals namely Ecoterex, Lambda cyhalothrin and Cabaryl on the incidence of FAW attack on maize.
c) Determine the interaction between the variety and method of chemical treatment on maize productivity.

1.5 Research Questions

a) Are there different levels of tolerance to FAW attack in maize varieties?
b) Are there different levels of effectiveness among the three chemical treatments in the control of FAW on maize?

1.6 Significance of the study

The common management strategy for the FAW in the Americas has been the use of insecticide sprays and genetically modified crops (Bt maize). On the African continent in general and in Zimbabwe in particular, there is no inventory of registered pesticides that can effectively control the FAW (FAO). There are also no registered Bt maize varieties on the Zimbabwean market. In many African countries, soon after the occurrence of FAW infestation, a massive spraying programme of chemical insecticides was deployed by governments of African countries. However, most smallholder farmers in Africa cannot afford repeated sprays of insecticides and Bt maize is not available in Africa. Furthermore, excessive use of chemical insecticides removes potential natural enemies, negatively impacts human and livestock health, leads to resistance development in target pests and increases crop production costs. In general, the excessive usage of insecticides and associated risks has raised food safety and sustainability concerns (FAO) 2017. This highlights the need for development of integrated pest management (IPM) strategies that suit the needs of the African smallholder farmers. The starting point in developing an IPM programme for FAW management is to identify maize varieties that are tolerant to FAW attack. In the same vein it is also important to evaluate insecticides that are effective but not harmful to non-target organisms. The results from this trial will therefore be disseminated to farmers on the response of different maize varieties to FAW attack as well as building on the inventory of effective insecticides in Zimbabwe.

Furthermore, FAW being a recent invader in the continent, information on natural enemies associated with this pest is not well-documented for Africa. International trade will possibly also be impacted by FAW as trading has the risk of introducing the pests to other countries where the pest will not have reached. Consignments of food and agricultural products are a particular risk, henceforth countries in North Africa, Asia and Europe will possibly manage this risk by introducing other production or handling requirements and conditions on exports from the countries affected by FAW thus creating cost implications for the exporters. In June 2017, the first shipment (of roses) from Africa infested with the FAW was intercepted in Europe (Day *et al*., 2017). Appropriate measures have been taken by National Plant Protection Organizations (NPPOs) which have significant exports to Europe. Well organized

NPPOs are most likely able to deal with the situation but in countries where export certification is weaker and in countries where the agrifood export sector is less developed it could be a big problem (Day *et al*., 2017). The study aims at generating knowledge that will be useful in the fight against the fall armyworm. Such knowledge will help to avoid losses being faced by farmers due to outbreak of fall armyworm on maize. Lessons from the study will be used to inform farmers about the fall armyworm control and prevention strategies. In the final analysis, the overall objective of the study will be to increase maize production and alleviate hunger to the nation as well as to increase income to the farmers due to control of fall armyworm.

1.7 Delimitation of the Study

The experiment was conducted at Mangwiro Farm in Mashonaland East Province under the Beatrice Area of Seke district. The Farm is located at coordinates 18.25^{0}S 30.85E and 1307m above sea level. The soils are sandy (Fersallitics) according to Zimbabwe soil classification system by (Thompson 1965). The temperatures range from 15^{0}C to 18^{0}C in winter and 25^{0}C to 32^{0}C in summer. The amount of rainfall per year normally ranges from 800mm to 1000mm. The farm lies in the Agro-ecological zone II b of Zimbabwe according to (AGRITEX). The experiment was carried out with three maize varieties SC513, SC529 and PAN53.The study was conducted from November 2019 to April 2020.

1.8 Limitation of the Study

During the course of the trial, there was a prolonged dry spell in the Month of January 2020 and this retarded crop growth to a significant extent. Supplementary irrigation was use to salvage the trial. Subsequent rains as from February 2020 were adequate to enable the crop to reach maturity.

CHAPTER 2 REVIEW OF RELATED LITERATURE

2.1 Introduction

Maize (*Zea mays* L.) is one of the main and popular cereal crops due to its high value as a stable food, as well as its Stover demand for animal feed and fuel and even for construction purposes (Abebe & Feyisa, 2017). Maize is also the most important staple crop in terms of calorie intake in Zimbabwe. Approximately 88% of maize produced in Zimbabwe is used as food, in both green cobs and grain (AGRITEX, 2015). Because of its multiple advantages, it ranks second in production area, next to other cereals, but first in its productivity among major cereal crops (Abate *et al*., 2015).In Africa, FAW infestations are occurring in "outbreak" style in many maize-production areas large populations of the pest are found in the fields and cause damage. As the pest is new to Africa, natural enemies are still rare, though some local species seem to be able to feed on FAW and reduce its populations. It is possible that FAW is now reaching "peak" levels in Africa. Within a few years, as natural enemy populations catch up and spread, a lower equilibrium population of FAW could be present in Africa. It is therefore important to preserve and enhance natural enemy populations in Africa (FAO, 2018).

FAW is a polyphagous lepidopteran pest that is indigenous throughout the Americas (Blanco *et al*., 2016; Cruz *et al*., 2012; Prasanna, Huesing, Eddy, &Peschke, 2018). It can be very destructive throughout the year, feeding in large numbers on the leaves and stems of more than 100 plant species (Pogue, 2002). Economically important cultivated host crops include maize, millet, wheat, potato, soybean, cowpea, peanuts, sorghum, rice, sugarcane, even vegetables and cotton (CABI, 2017c; Pogue, 2002). The favourite spot of the caterpillar stage of the FAW is curled up in the whorl of a maize plant, where it feels protected and chews and grows on its favourite food tender, young maize leaves. As they chew away, the leaves continue to grow out; leaving ragged, half-chewed leaves that are typical of FAW infested maize fields. Sometimes, but much less often, FAW can act as a young plant cuter, if high populations of the caterpillar are present on weeds or other host plants in fields adjacent to newly planted maize fields. This Armyworm-like action by FAW is rare, but can occur. At very high population levels FAW can also penetrate maize ears, causing direct damage to the harvest. But again, this is rarer than the typical behavior of burrowing down into the whorl to eat leaves.

Some 8 to 14 days old larvae can cause severe damage to maize plants, especially when the growing points of young plants are eaten. Early vegetative-stage FAW infestation can cause more leaf damage and yield losses than late vegetative stage infestation. Fortunately, maize plants can significantly recover (compensate) from early growth stage damage on leaves and short duration defoliation. When the FAW population is high on a plant, the adult larvae might occasionally move to the tassel and the ears, reducing the quality of the produce at harvest. Heavy rains can wash young larvae off leaves, and drown those in the whorl. However, it has now invaded Africa (Day *et al*., 2017; Goergen, Kumar, Sankung, Togola, &Tamo, 2016) and is rapidly spreading throughout tropical and subtropical regions of the continent. It was first detected in 2016, in Nigeria, Sao Tome and Principe, Benin, and recently in Togo.

FAW is most likely to have an effect on numerous diverse aspects of household livelihoods. The pest is most likely going to affect natural capital, through the loss of yields. International trade will possibly also be impacted by FAW as trading has the risk of introducing the pests to other countries where the pest will not have reached. Consignments of food and agricultural products are a particular risk, henceforth countries in North Africa, Asia and Europe will possibly manage this risk by introducing other production or handling requirements and conditions on exports from the countries affected by FAW thus creating cost implications for the exporters. In June 2017, the first shipment (of roses) from Africa infested with the FAW was intercepted in Europe (Day *et al.*, 2017). Appropriate measures have been taken by National Plant Protection Organizations (NPPOs) which have significant exports to Europe. Well organized NPPOs are most likely able to deal with the situation but in countries where export certification is weaker and in countries where the agrifood export sector is less developed it could be a big problem (Day *et al*., 2017).

2.2 Theoretical conceptual Framework

Current maize productivity is below its potential, although still higher than that of other major cereal crops. The low yield is attributed to a combination of several production constraints mainly lack of improved production technologies such as pest management practices, moisture stress, low fertility and poor cultural practices (Tufa & Ketema, 2016). Arthropod pests are among the key factors contributing to low yields facing maize production today. More than 40 species of insects have been recorded on maize in the field. Of these pests, the maize stalk borer (*Busseola fusca)*, spotted stalk borer (*Chilo partellus*), and various termite species (*Macrotermes* and *Microtermes* spp.) have long been recognized as key pests, but a more recent invasive species, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), commonly named fall armyworm (FAW), is now the major insect pest causing substantial yield losses of maize in Zimbabwe. (AGRITEX, 2018).

2.3 Relevance of the Theoretical Framework to the study

The Fall Armyworm (FAW) (*Spodoptera frugiperda*) is a Lepidopteron pest that feeds in large numbers on leaves and stems of more than 100 plant species, causing major damage to economically important cultivated grasses such as maize, rice, sorghum, sugarcane as well as some vegetable crops and cotton (Ali *et al*. 1989; Ashley *et al*., 1989; Capinera, 2000). Research has shown that the Fall Armyworm could destroy 40–70% of maize yield (Day *et al*., 2017). Capinera, (2000) suggested that the worm can reproduce and spread quickly given the right environmental conditions. The feeding stage (larval stages) takes between 10 and 21 days if the worms are not controlled (Prasanna *et al*., 2018), after which the larvae change into pupae to produce new adults that lay eggs. One adult can lay between 1000 and 1500 eggs (Capinera, 2000) which hatch into feeding larvae. According to Rose *et al*., (1975), the moth of the FAW can travel up to 2000 km each year in search of warmer climates.

The pest and other similarly destructive invasive species are especially devastating to rural communities in developing countries that depend on farming for both food security and their livelihoods. In addition, the worsening impact of climate change, drought and flooding, exacerbated the fall armyworm situation in Ghana and other African countries by creating the ideal conditions for the pest to survive and thrive in the environment. Report by the FAO (2019) informed that about 200 million people in Africa depend on maize as a staple in their diet. The fall armyworm infestation could potentially reduce crop yields by 21%to 53%over a three-year period across African countries where the pest has been found (Maes, 2018). The FAW has caused Africa over $13 billion as experts warn the pest has come to stay on the continent (All Africa 2018; Kebede, 2018). The FAW was first reported in 2016 in the Yilo Krobo district of the eastern region (MOFA, 2017). The pest destroyed 1.4million hectares of maize and cowpea farms in six regions of Ghana in 2016 and has destroyed over thousand hectares of farms already in the 2017 cropping season (SARI, 2017).

In Ghana, The Ministry of Food and Agriculture (MoFA) has so far procured 72,774 liters of liquid pesticides and 4320 mg of powered pesticides for application of in the affected areas. Also, MoFA, in collaboration with the United States Agency for International Development, (USAID) procured 1000 knapsacks sprayers for the three northern regions and has also provided training for their usage. Less than a year after assurances by Ghana government and a GHS 15.9 million budgetary allocation to eradicate the FAW. This procedure should be followed in Zimbabwe to eradicate fall armyworm before doing excessive to maize and other cereal crops.

2.4 Promising management options for the Fall Armyworm

The most promising options for the management of FAW by African smallholders are presented as follows:

2.4.1 Seeds and varieties

Seed treatment might prevent early damage of the seedlings after germination. Longer-term solutions of resistant or tolerant maize varieties might have potential, but are several years off FAO recognizes that crop improvement through innovative technologies, including both conventional breeding and modern biotechnologies, is an essential approach to achieving sustainable increases in crop productivity and thus contributes to food security. Scientific evidence has shown that modern biotechnologies offer potential options to improving such aspects as the yield and quality, resource use efficiency, resistance to biotic and abiotic stresses, and the nutritional value of the crops. The FAO is also aware of the public perception and concerns about the potential risks to human health and the environment associated with genetically modified organisms (GMOs). FAO underlines the need to carefully evaluate the potential benefits and possible risks associated with the application of modern technologies. The FAO emphasizes that the responsibility for formulating policies and making decisions regarding these technologies rests with the Member Governments themselves. The responsibility for formulating policies and making decisions regarding GMOs lies with the individual Governments.

2.4.2 Use of Genetically Modified Maize Varieties

Regarding the potential use of GM (genetically modified) maize to control the FAW in Africa, FAO considers that it is yet too early to draw conclusions. Bt maize has been demonstrated to decrease damage from FAW, but FAW populations in the Americas have evolved resistance to some Bt maize varieties. The primary target pests of Bt are specific insect species. Bt controls insects with toxins called insecticidal crystal proteins or delta endotoxins. When insects ingest toxin crystals, which are then dissolved and cut with proteases in the highly alkaline of insect midgut, making the cry toxin release from the crystal. The Cry toxin is then inserted into the insect gut cell membrane, paralyzing the digestive tract and forming a pore, which makes the insect stop eating and starve to death. Nevertheless, more work still needs to be done including conducting trials and collecting data. It must be kept in mind that the Bt maize grown currently in some parts of Africa is used primarily for controlling the maize stem borer insect and not FAW. Maize has been genetically engineered by incorporating genes from the bacterium *Bacillus thuringiensis* (Bt) that produce insecticidal proteins that kill important crop pests. The use of Bt maize has resulted in some cases in reduced insecticide use, pest suppression, conservation of beneficial natural enemies and higher farmer profits. However, such benefits may be short-lived. Insect populations are able to adapt to Bt proteins through the evolution of resistance. Despite efforts to delay the selection for resistance, many cases of field resistance evolution among maize pests have been demonstrated in Bt maize, including in the FAW (*Spodoptera frugiperda*) in the Americas, and in South Africa in the maize stem borer (*Busseola fusca*). While transgenic maize has provided some transitory benefits to commercial maize farmers, the context for the vast majority of African maize farmers is quite different. Over 98 percent of maize farmers in Africa are smallholders, growing maize on less than 2 ha of land and typically saving seed to plant the next crop (FAO) 2018.

To delay resistance development, the United States and Canada have implemented an IRM plan named the 'high dose/refuge' strategy for planting Bt crops (Ostlie *et al*., 1997; Gould, 1998; Baute, 2004). This strategy firstly aims to use 'high-dose' Bt plants to kill resistant heterozygotes of the target pests (US EPA, 2001). Thus the resistance alleles of resistant heterozygous insects can't be transmitted into the next generation. Secondly, the remaining area is planted to non-Bt varieties that serve as a refuge for susceptible insects. The susceptible insects emerging from the non-Bt crop should mate with the rare resistant homozygous individuals that have survived on the Bt crop. If the frequency of resistance is very low (e.g. 0.001), majority of offspring carrying resistance alleles will be heterozygous and the heterozygotes should be killed by the high doses Bt crops (Huang et al., 2011). Through this strategy, the resistance allele frequency in the target pest populations can be maintained at low levels for a long-period of time. There are three key assumptions for the success of the "high does/refuge" IRM strategy (Huang *et al*., 2011). First, the Bt crops should produce a high dose of Bt proteins that can kill the individuals of the target species that carry one copy of the resistance allele. In other words, the resistance should be functionally recessive. Second, the initial resistance allele frequency should be very low, usually <0.001. And finally, the rare survivors that are homozygous for resistance can mate with the susceptible individuals from the non-Bt refuge plants (Ostile *et al*., 1997; US EPA, 2001). Previous studies have demonstrated that resistance development to Bt crops in target pest populations can be significantly delayed if these three assumptions are met (Huang *et al*., 2011).

2.4.3 Crop management

Management of FAW in maize fields begins with prevention. Planting dates: avoid late planting, and avoid staggered planting (planting of fields at different dates in the same area), as this would continue to provide the favored food of FAW locally (young maize plants). This is one of the most important recommendations for smallholders. Good soil health and adequate moisture are critical: they are essential to grow healthy plants, which can better withstand pest infestation and damage. Also, unbalanced inorganic fertilization of maize (especially excessive nitrogen use) can increase oviposition by female FAW. The efficacy of managing crop residues to break the life cycle of FAW generations is not well established by research. It also runs counter other recommendations to maintain soil cover to improve soil health for sustainable production.

2.4.4 Response of Maize to FAW damage

Maize has been selected by humans for thousands of years to yield well, even in face of damage to insects, pathogens and other threats. The advantage of selection has resulted in maize plants that have considerable capacity to compensate for foliar damage. The response of maize yield to FAW infestation has been studied in the field a number of times in the Americas. A review of these studies shows that while of concern, FAW damage in maize is not devastating (FAO) 2018. While a few of the studies shows yield reductions due to FAW of over 50 percent, the majority of the field trials show yield reductions of less than 20 percent, even with high FAW infestation (up to 100 percent plants infested). Maize plants are able to compensate for foliar damage, especially if there is good plant nutrition and moisture. While FAW needs to be managed sustainably by farmers, it is not cause for panic (FAO) 2018. Fall Armyworm populations are affected by plant quality. An important factor that effects FAW populations is the quality of the plant. The nutritional quality of plants affects not only plant growth and plant capacity to compensate for foliar damage by pests; but it also influences indirectly herbivore (i.e. FAW) growth and mortality and infestation levels. Several studies have shown the effect of fertilization on maize on FAW larval growth and mortality, but sometimes there is even a difference in the type of fertilizer (FAO) 2018. Several studies have shown a difference between chemical fertilizer and organic fertilizer (manures). In Brazil, chemical fertilizer resulted in significantly higher levels of FAW infestation in maize than treatments with no fertilizer used, or organic fertilizer.

2.4.5 Plant diversity

Diversity on farm reduces Fall Armyworm infestation and supports natural enemies. Another very important aspect of prevention of FAW infestations is by maintaining plant diversity on farms. Even if many female moths are flying about, if she does not lay her egg masses on maize plants, or if very young larvae do not move onto maize plants, then the maize will not be infested by FAW.FAW moth prefer maize to lay her eggs. In large monocultures of maize, she just flies about, laying her eggs in a sea of maize. When maize is intercropped with other crops or there are other plants nearby that she does not like, she is more likely to move on, skipping maize plants that may be mixed in with the plants she doesn't like. This is the first step in good FAW management – reduce oviposition on maize plants. Farmers in Central America have noticed that when they plant maize together with other crops such as beans and squash (their traditional "milpa" systems), they have less pest attacks. Agro ecologists have documented that polycrops may be effective because of for main reasons or mechanisms: One possible explanation is that a diversity of plants in the same field confuses FAW, and it is difficult for it to find its preferred host plant (maize), eating less or laying fewer eggs. Another reason is that the female FAW moth does not like certain plants because of the chemicals they emit. The volatile compounds are the "push" effect in push-pull systems, which "push" pest 'species away from certain plants while they are "pulled" to others because the plant chemicals make them more attractive. So, planting maize near other plants that "push" FAW moths away is the first step in preventing FAW infestation. A third possible explanation is that poly-cropping may provide natural enemies (parasitoids and predators) with resources such as nectar; water; or a place to hide, and those natural enemies will control FAW.A fourth rationale for the intercropping is that it increases soil organic matter, and in the case of legumes it increases Nitrogen, which improves plant health, making it more able to compensate for FAW damage In Mesoamerica, plants such as *Tagetes lucida*, *Coriandrum*, *Sonchu soleracea*e, *Ruta* and onions, attract beneficial insects.

2.4.6 Push-pull technology

Push-pull is a habitat management strategy developed and implemented to manage pests such as stem borers, *Striga* weed and address soil degradation, which are major constraints in maize production in Africa. The technology entails using a repellent intercrop (*Desmodium* as a "push") and an attractive trap plant (Napier/*Brachiaria* grass as a "pull"). The Napier grass planted around the maize farm, attracts stem borers and FAW to lay eggs on it, but it does not allow larvae to develop on it due to poor nutrition; so very few larvae survive. At the same time, *Desmodium*, planted as an intercrop permits volatiles that repels stem borers or FAW, and secretes root exudates that induces premature germination of striga seeds and kills the germinating striga; so this depletes seed banks of striga in maize farms over time covers the ground surface between maize, thus smothering weed so enriches the soil with nitrogen, preserves soil moisture and protects the soil from erosion. The *Desmodium* and Napier/Brachiaria grass grown in Push-pull farms also provide valuable biomass as fodder for livestock, which can translate into increases in dairy products like milk. Hence, Push-pull technology appears effective in controlling FAW, with associated maize grain yield increases under the conditions tested. This technology could be immediately deployed for management of the pest in Africa and in areas with similar conditions. Further testing in other agro ecological zones is needed (Midega *et al*. 2018). “Push-pull climate smart” (combination of *Desmodium* Greenleaf and Bracharia cv Mulato II): is designed for dry and hot conditions to address the challenges posed by climate change Brachiaria grass grows fast with less water, and has been found to tolerate dry conditions better than Napier grass. Push–pull is an effective and efficient low-cost technology as it addresses some major constraints faced by smallholder farmers. The multiple benefits of this technology can result in an overall and significant improvement of farmer’s food security and livelihoods.

2.4.7 Mechanical control

A very important management option for smallholder farmers in Africa, based on the experience of smallholders in the Americas, is to visit their fields regularly, and crush egg masses and young larvae (use your fingers, not pesticides). Farmers should visit fields twice a week during vegetative stage, especially in periods of heavy oviposition by FAW, and once a week or every 15 days in later stages. Some smallholder farmers in the Americas report using ash, sand, sawdust or dirt into whorls to control FAW larvae. Ash, sand and sawdust may desiccate young larvae. Dirt may contain entomopathogenic nematodes, Nucleopolyhedrosis Virus (NPV), or bacteria (such as *Bacillus* sp.) that can kill FAW larvae. Smallholder maize farmers in Central America and in Africa also report using lime, salt, oil and soaps as control tactics. Lime and ash are very alkaline. They also use local botanicals (neem, hot pepper, local plants) and some farmers report success (FAO) 2018). Other farmers recycle the naturally-occurring entomopathogens, by collecting the larvae killed by virus or fungi, grinding them, straining the body parts out (leaving just the fungal spores or viroid particles), mixing this filtrate with water and spraying it back into the whorls of infested plants (FAO) 2018. Some FFS farmers report effectively pouring water in the maize whorl to drown the larvae. Other farmers in Central America and in Africa use sugary sprays, oil or lard, ‘fish soup’ or other material to attract ants and wasps to the maize plants. The predatory ants are attracted to the lard, oil, bits of fish parts, or sugar; once on the maize plants, they also find and eat FAW larvae. Farmers in Benin reported picking larvae to feed them to chicks for poultry production (FAO)2018.

2.4.8 Biological control of the Fall Armyworm

The Fall Armyworm has many naturally-occurring ‘natural enemies’ or ‘farmers’ friends. These biological control agents are organisms that feed on FAW. In the Americas, and probably in Africa, these natural enemies can be active during all development phases of FAW, (FAO) 2018 in the egg, larval, pupal and adult stage. Natural enemies have the potential to substantially reduce the FAW populations and hence the damage caused by FAW. This impact however depends on a number of factors including the diversity of organisms being active, their life-style, local presence, numerical and timely abundance, host specificity, agronomic practices, and pest management methods. A major challenge is to create conditions to exploit the potential of these beneficial organisms to their full extent. Broad spectrum pesticides kill many of the farmers’ friends. It is important that farmers recognize the pest in all its development stages, its associated natural antagonists, identity possible gaps to be filled in local natural enemy guilds and at the same time sustain their action by adequate management measures in an IPM context. Biological control agents (BCAs) include the following: predatory insects and mites, which eat their prey; parasitoids, which are insects with a free living adult stage and a larval stage that is parasitic on another insect; and parasites and microbial pathogens, such as nematodes, fungi, bacteria, viruses and protozoa, which cause lethal infections.

2.4.8.1 Parasitoids of the FAW

A parasitoid is an organism that lives in a close association with its host at the host expense, eventually resulting in the death of the host.

The larvae of parasitoids always kill their host as the outcome of their development. The majority of parasitoids known to be associated with the FAW are wasps, and less frequently flies. Species that have undergone an adaptation process to the FAW display a narrow host range. Such co-evolved parasitoids can exert a strong impact on populations of the FAW and are thus good candidates for use in biological control programs. The following are some of the most common parasitoids known to be well adapted to the FAW in the Americas.

2.4.8.2 *Telenomus remus* Nixon (Hymenoptera: Platygastridae)

Identification: minute wasp of about 0.6 mm size with black shiny body. The wings are transparent and have reduced venation. Female antennae have 11 segments whereby the last 5 are enlarged forming a club. Males have 12 antennal segments of equal size.

2.4.8.3 *Chelonus insularis* Cresson (Hymenoptera: Braconidae)

Identification: parasitoid of about 5 mm size characterized by a carapace-like abdomen. A white band medially divided can be observed at the base of the abdomen. Wings bear numerous veins. Antennae of both sexes are filiform and have 16 segments or more.

2.4.8.4 *Cotesia marginiventris* Cresson (Hymenoptera: Braconidae)

Identification: Male and female average 3 mm in length. While the head and thorax of adults are black, the abdomen is tan. The antennae are long segmented and slighter shorter than the body length. Females can be recognized by a very short ovipositor at the tip of the abdomen.

2.4.8.5 *Trichogramma* spp. (Hymenoptera: Trichogrammatidae)

Identification: There are numerous species of the genus Trichogramma known to develop inside the eggs of the FAW and of many other Lepidoptera. Typically, Trichogramma spp. are tiny wasps less than 0.5 mm long. Adults are mostly orange, brown or even black. Antennae are short, clubbed in females and hairy in males.

2.4.8.6 Fly parasitoids: *Archytas, Winthemia* and *Lespesia* (Diptera: Tachinidae)

Identification: Several fly species of the family Tachinidae are able to develop on FAW caterpillars. Attacks by such parasitoids can be detected either when small maggots are visible in presence of FAW caterpillars, or tiny white eggs are observed on their skin. Alternatively, fly pupae can be found nearby dead FAW larvae.

2.4.9 Predators of the FAW

In this category there are natural enemies that kill one or several individuals of FAW during their life time either as larvae or adults. In this case, eggs, caterpillars, pupae or adult FAW are considered as preys. Usually predators are non-selective or generalists, thus they feed opportunistically on more than one host species, sometimes even on their own kind.

2.4.10 Earwigs (Dermaptera: Forficulidae, Carcinophoridae)

Two species are currently recognized to play a significant role as FAW egg predator in maize crops: *Doru luteipes* (Scudder) and *Euborellia annulipes* (Lucas).

2.4.11 Ladybird beetles (Coleoptera: Coccinellidae)

Both adults and larvae of ladybugs feed on various phytophagous insects such as mites, aphids, scales, mealy bugs, eggs and young larvae of Lepidoptera including the Fall Armyworm. *Coleomegilla maculata* DeGeer, *Cycloneda sanguinea* (Linnaeus), *Hippodamia convergens* Guérin MenevilIe, *Eriopis connexa* Mulsant, Olla v-nigrum Mulsant, *Harmonia axyridis* (Pallas) and *Neda conjugata* (Mulsant) are species commonly found in maize fields in the Americas.

2.4.12 Ground beetles (Coleoptera: Carabidae)

Many carabid beetle species occurring in maize cropping are known for their predatory habits both as larvae or adults. *Calosoma granulatum* Perty has been observed to feed on young FAW caterpillars.

2.4.13 Assassin and flower bugs (Hemiptera: Reduviidae, Pentatomidae, Geocoridae, Nabidae, Anthocoridae)

There are several species of bugs that have been observed to feed on immature of the FAW. The best known of this category belong to the genera *Zelus* (Reduviidae), *Podisus* (Pentatomidae), *Nabis* (Nabidae), *Geocoris* (Lygaeidae), *Orius* and *Anthocoris* (Anthocoridae).

2.4.14 Ants (Hymenoptera: Formicidae)

Ants are often among the most important predators of FAW larvae and pupae. Perfecto (1980) studied the interactions among ants, FAW and pesticides in maize systems in Nicaragua. She found that ants are very important predators of FAW in maize in Nicaragua and that pesticides dramatically reduced the presence and effectiveness of ants a natural biological control of FAW.

2.4.15 Birds and bats

Birds and bats have been observed to prey on FAW larvae. Studies in Central America have demonstrated significant impacts of birds on infestation levels of the FAW. Presence of trees or bird perches in or near fields will help attract birds that can prey on the FAW and help control their population.

2.4.16 Entomopathogens

Pathogens (microorganisms that can cause disease) are everywhere. In agriculture, plant pathogens (fungi, bacteria, viruses, nematodes) affect plants, reducing yield or quality. Also very important, but less perceived by farmers, are entomopathogens, those pathogens that affect insects. The Fall Armyworm is naturally affected by several different types of pathogens: Viruses, in particular Nuclear Polyhedrosis Virus (NPVs) such as the *Spodoptera frugiperda* Multicapsid Nucleopolyhedrovirus (SfMNPV). Fungi, in particular *Metarhizium anisopliae*, *Metarhizium rileyi*, *Beauveria bassiana*, Bacteria, such as the *Bacillus thuringiensis* (Bt), Nematodes and Protozoa. They have also already been observed killing FAW larvae in the field in Africa, so they are already present, at least in some farmers' fields. The host-specificity of these pathogens is quite high, usually restricted to a few closely-related insect species. These pathogens do not affect other groups of insects (natural enemies), plants, animals or humans. FAW larvae naturally killed by viruses and fungi are easily identified in the field. Virus-killed larvae become soft and many hang from leaves, eventually oozing viroid particles and fluids. Fungal killed larvae turn rigid and appear "frozen" on the leaves, eventually turning white or light green, as the fungal spores mature. These are the two most common groups of entomopathogens naturally killing FAW larvae in the field. Farmers can learn to recognize these 'farmer-friendly' pathogens in the field. They can also multiply them locally. Farmers in the Americas sometimes collect the dead and dying larvae, full of viroid particles of fungal spores (the infective stages of the pathogens), grind them up in kitchen blenders. Then they strain the larval body parts out, mix the concentrated filtrate of virus or fungus with water, and spray them back out into the field, especially directly into maize plants currently infested with FAW.

Entomopathogens can play a very important role in natural regulation of FAW populations in the field. Farmers should learn how to identify the different organisms, understand their biology and ecology, and begin to experiment with them! They are truly farmers' friends!

2.5 Botanical pesticides for Fall Armyworm management

The use of plant-derived pesticides (commonly called "botanicals") in pest management is a cultural practice of most African farmers. It could provide a potential arsenal against the fall armyworm in Africa. The mode of action of botanical pesticides is broad and ranges from: repellency, knock-down, larvicidal to anti-feed and molting inhibitors and growth regulation. They have a broad-spectrum activity with generally little or no mammalian toxicity; however, some botanical pesticides are highly toxic not only for pests but also for natural enemies and for mammals including humans, for instance tobacco extracts. Pyrethroids will also affect natural enemies. Farmers generally extract bioactive compounds as a concoction after grinding plant materials using water. Essential oils from bioactive rich plants and powdered forms are also used to some extent. Several plants extracts have been reported to have insecticidal properties against stem borers in cereals. These include Neem, *Azadirachta indica*; Persian Lilac, *Melia azadirach*; Pyrethrum, *Tanacetum cinerariifolium*; Acacia, *Acacia* spp; Fish-poison Bean, *Tephrosi avogelii*; Wild marigold, *Tagetes minuta* ;wild sage, *Lantana camara*; West African pepper, *Piper guineense*; Jatropha, *Jatropha curcas*; Chillies, *Capsicum* spp; onion, *Allium cepa*; Lemon grass, *Cymbopogon citratus*; Tobacco, *Nicotiana* spp; Chysanthemum, *Chrysanthemum* spp; Wild Sunflower, *Tithonia diversifolia* (Ogendo *et al*., 2013;Mugisha-Kamatenesi *et al*., 2008; Stevenson *et al*., 2009, 2017). Preliminary evidence indicates that seeds or leaves of plants of the Meliaceae family (*Azadirachta indica*, i.e. neem and Melia) and Asteraceae family (Pyrethrum) and other plants such as *Tephrosia vogelii*o and *Thevetiane riifolia* are showing efficacy in the management of armyworms.

2.5.1 There are comparative advantages associated with the use of botanicals:

They are biodegradable and do not accumulate in the environment generally less harmful to farmers and consumers (though there are some exceptions); and they often are less toxic to natural enemies (predators and parasitoids), hence not disrupting ecosystem services delivered by these natural enemies.

2.5.2 Synthetic pesticides

It is recommended that farmers use an Integrated Pest Management approach with the use of low-risk pesticides as then last resort. Within the group of low-risk pesticides, bio pesticides are considered to be the best option. If there are temporary constraints to the use of bio pesticides, low-risk pesticides, products falling under WHO hazard classes III and U, can be considered.

2.6 Summary

Within the sub-Saharan African countries, in which populations of FAW (*Spodoptera frugiperda*) exist, farmers for maize crop experience attack by the pest and yield loses in maize, millet, sorghum, rice, wheat, and sugarcane (FAO, 2017). Attracted by nutritious crops FAW destroys substantial amounts of harvest by feeding on crops. As this pest species is difficult to eradicate and therefore cannot be absolutely eradicated, new ways are being investigated to repel or ward off the pest from the crop fields.

CHAPTER 3 METHODOLOGY

3.1 Experimental site

The experiment was conducted at Mangwiro Farm in Mashonaland East Province under the Beatrice Area of Seke district. The farm is located at coordinates 18.25^0S 30.85E and lies at about 1307m above sea level. The soils are sandy (Fersiallitics) according to Zimbabwe soil classification system (Thompson 1965). The temperatures range from 15^0C to 18^0C in winter and 25^0C to 32^0C in summer. The amount of rainfall per year normally ranges from 800mm to 1000mm during summer time.

3.2 Varieties used in the experiment.

Three maize varieties were used and these were:

- SC513-Seed Co medium early maturity variety and can tolerate diseases and pests. Can yield between 5 tonnes to 10 tonnes per hectare under good agronomic practices. Its drought tolerant and can thrive well in 600 to 800mm of rainfall.
- SC529-Seed Co medium early maturity varieties and is resistant to pest and diseases. Its drought tolerant and can yield from 7 tonnes to 12 tonnes per hectare under good agronomic practices. Can thrive under 600mm to 800mm of rainfall.
- Pan 53-medium hybrid variety and it's also resistant to pests and diseases and can yield 5 to 10 tonnes under good agronomic practices (GAP). This variety is from Pannar and it is said to be drought resistant.

The varieties were chosen because they are medium early maturity varieties which could fit well with time of the project and analysis of data was going to be done on time.

3.3 Experimental design and Treatments

The experiment adopted a factorial experiment in a randomized complete block design in which the treatments consist of all possible combination of the selected levels. in two. There were four treatments, each with four lines which were three meters long and replicated three times and overall it was a 3X4 factorial experiment. Each variety was replicated three times and the total number of plots was thirty-six and the experiment was consisting of three blocks and each block had twelve plots. Inter-row spacing was 0.90cm and in row was 0.20cm within the plots. Inter-row between blocks was 1.5m and inter-row within the block was 1m. Each plot was holding sixty plants and the whole block had total of seven hundred and twenty plants with four treatments and each line was holding fifteen plants which was three meters long. Within the plots, there was a net plot where samples were collected per each plot. There were controlled and uncontrolled treatments.

3.4 Trial management

3.4.1 Land preparation

Tillage was done using a tractor drawn disc which creates a fine tilth by ploughing to a depth of 20 cm. the land was cultivated previously therefore there was no need for deep ploughing. The rows were marked perpendicular to the direction of slope. A line was stretched across the field and used to mark straight rows which were 90 cm from each other. Furrows were opened in the rows using hoes to represent the plots in which each treatment was to be planted. The soil analysis was done before land preparation and soil test analysis was done at Windmill laboratories in Harare, the pH was 5.2 and we did not apply lime because maize can strive in less acidic soil.

3.4.2 Planting

Planting was done on the 10th of December 2019. The seed was obtained from Seed Co and Pioneer Seed Companies. Planting was done by hand with an intra-row spacing of 0.90m and an in row spacing of 0.20m which gave 60 plants in each plot. The seed were covered with soil to a depth 10cm.

3.4.3 Fertilization

Compound D (7:14:7) Nitrogen 7%, Phosphorus 14% and Potassium 7% was applied as the basal fertilizer at a blanket rate of 400 kg/ha. The fertilizer was covered with soil to prevent direct contact with the seed as this may burn the seed. The top dressing was applied at 300 kg/ha of (34.5%) ammonium nitrate.

3.4.4 Crop Protection

For control of fall armyworm three chemicals were used namely:

Ecoterex--a granular stomach and contact insecticide for control of fall armyworm and 3-4kgs/ha was used.

Lambda Cyhalothrin SEC--insecticide synthetic pyethroid.200ml/ha was used.

Cabaryl--contact and stomach insecticide and 550g/ha. The plant should be thoroughly wet.

These three chemicals were randomly applied on plots and control plots were not sprayed with any chemical.

3.4.5 Irrigation

Irrigation was done to prevent water stress as this has negative effect on yield. The most sensitive growth stages of maize to water stress are flowering and cob setting. Therefore, water had to be applied artificially using an overhead irrigation system for six hours to achieve field moisture of 30mm and the irrigation schedule was every after seven days.

3.4.6 Weeding

Weeding was done using hoes to remove weeds such as Mexican clover, upright starbar, pigweed and gallant soldier. Weeding was done to prevent crop maize and weeds competition for nutrients, water and air.

3.4.7 Harvest

Harvesting was done after 18 weeks. The tassels of the maize plants and leaves had been completely wilted and this was an indicator of maturity. The cobs were taken from the plant when 95 % of the tassels and leaves were dried and the cobs left to dry for two weeks. Harvesting was done using hands and put into sacks for easy of handling the cobs.

3.4.8 Weighing

The grains from cobs were shelled using hands and grains of maize from each plot were weighed and mass was recorded for each plot. Biomass was recorded for each plot and the mass was recorded. The weight of the harvested grains was obtained using an electronic scale.

3.4.9 Notable pests and diseases

Regular scouting was done to take note of infestations, signs and symptoms of pests and diseases.

3.5 Data Collection

3.5.1 Days to maturity.

Wilting of the maize leaves and tassels for plants are a characteristic of physiological maturity. The number of days to physiological maturity was taken from the day of planting to the day of harvesting when all of the leaves had been dried.

3.5.2 Plant count.

Number of plants per plot was recorded by physical counting the number of plants present in each plot after emergence ceased.

3.5.3 Plant height (cm).

The figures for plant height were obtained using a tape measure to measure from the base of the plant to the plant tip in randomly selected sample of six plants from each replicate plot and the average was calculated.

3.5.4 Appearance or plant vigor.

The information was recorded from after germination, until 14^{th} week through visual observation of the plants plots basing on stem thickness, leaf size and height. Using score of 1 up 9. One which is the best and 9 the poorest according (Cisser & Ejeta 2003: Adetimirin *et al*., 2006).

3.5.5 Grain yield per plot (t/Ha).

Grains per plot were weighed from each replicate plot and their average was calculated and recorded.

3.5.6 Total grains in tons per hectare.

Grains in each plot were weighed for each replication and then converted into yield per hectare as follows. Total grains yield (t/Ha) =Yield per plot (Kg)/Ha/Area of plot ($m^{2)}$ *10000m^2/1Ha*1tonne/1000 (kg).

3.5.7 Population of fall armyworms count on each plot

Data was collected on weekly basis for number of fall armyworms on each plot by physically counting them.

3.5.8 Determination of quality of the cobs per plot.

Six cobs were collected from each plot and quality was checked physically and plots were ranked from 1 up to 9. One which the best and 9 the poorest.

3.5.9 Number of leaves of plants per plot.

Number of leaves per plot were counted at week 10 to check if control and uncontrolled had different leaves. The leaves were counted physically.

3.5.10 Leaf size per plot (cm)

The leaves per plot were measured using tape measure to check if there is difference between controlled and uncontrolled plots.

3.5.11 Cob size per plot. (cm)

Cob size per plot was measured using tape measure to check if there is mean difference between controlled and uncontrolled plots.

3.5.12 Biomass of stalks per plot.

The mass of stalks was weighed using electronic scale to check the mean difference between controlled and uncontrolled plots.

3.6 Analysis and organization of data

Mean for all the parameters were analyzed using a statistical package GenStat version 5 used to conduct Analysis of variance (ANOVA). Means with significant differences were separated using Fishers protected Least Significant Difference (LSD) at p=0.05 level according to Gomez & Gomez, (1984).

CHAPTER 4 DATA PRESENTATION, ANALYSIS AND INTERPRETATION

4.1 Introduction

This chapter deals with the interpretation of results of the analyzed data.

4.2 Data Presentation and Analysis

4.2.1 Effect of chemical treatments on mean number of larvae per plot at 7 weeks after planting.

There were no significant differences (Pp>0.05) for the mean insect larvae numbers among the four treatments and between the three varieties at week 7 after planting (Table 1). There was no significant interaction between the treatments and the varieties (Table 1).

Table 1-Mean number of FAW larvae per plot at week 7 after planting.

	Variety			
Treatment	SC513	PAN53	SC529	LSDvar NS
Ecoterex	10.00	4.00	5.33	
Lambda	7.00	7.00	2.67	
Untreated	12.00	10.00	15.00	
Cabaryl	13.00	7.67	9.67	
$Pvalue_{treat}$	0.078			
$Pvalue_{var}$	0.344			
$Pvalue_{int}$	0.792			
LSDtreat	NS			
CV%	27			

4.1.1 Effect of chemical treatments on mean number of larvae per plot at 8 weeks after planting.

There was a significant difference ($p<0.05$) in the mean insect larvae numbers among the four treatments. The Ecoterex and lambda had significantly lower mean insect larvae numbers but were not significantly different from each other. The untreated control and Cabaryl were not significantly different from each other. The untreated control and Cabaryl were significantly different from both the Ecoterex and treatments. There were no significant differences ($p>0.05$) in mean insect numbers among the three varieties at the 8th week. (Table 2). There was no significant interaction between the treatments and the varieties (Table 2).

Table 2- Mean number of FAW larvae per plot at week 8 after planting.

	Variety

Treatment	SC513		PAN53		SC529		LSDvar NS
Ecoterex	9.7	a	3.0	a	3.7	a	
Lambda	5.7	a	11.0	b	1.0	a	
Untreated	16.7	b	11.0	b	15.0	b	
Cabaryl	20.3	b	9.3	a	10.0	b	
Pvaluetreat	0.030						
Pvaluevar	0.157						
Pvalueint	0.522						
LSDtreat	7.26						
CV%	77						

1- Figures followed by the same lowercase letter in the same column are not significantly different from each other at p=0.05.
2- NS= No significant difference at p=0.05

4.1.2 Effect of treatments on mean number of larvae per plot at 9 weeks after planting.

There was a significant difference ($p<0.05$) in the mean insect larvae numbers among the four treatments. The Ecoterex and lambda had significantly lower mean insect larvae numbers but were not significantly different from each other. The untreated control and Cabaryl were not significantly different from each other. These treatments were significantly different from both the Ecoterex and lambda treatments. There were no significant differences ($p>0.05$) in mean insect larvae numbers among the three varieties at the 9th week (Table 3). There was no significant interaction between treatments and variety at week 9 (Table 3). There were no significant differences across the three varieties for each treatment (Table 3)

Table 3-Mean number of insect larvae per plot at week 9 after planting

Treatment			Variety				
Treatment	SC513		PAN53		SC529		LSDvarNS
Ecoterex	7.3	a	2.3	a	1.3	a	

Lambda	3.3 a	10.3 b	0.7 a
Untreated	15.0 b	14.0 b	21.0 c
Cabaryl	15.7 b	9.7 b	11.0 b
Pvaluetreat	<0.001		
Pvaluevar	0.802		
Pvalueint	0.320		
LSDtreat	6.53		
CV%	72.1		

1- Figures followed by the same lowercase letter in the same column are not significantly different from each other at p=0.05.

2- NS= No significant difference at p=0.05

4.2.4 Effect of treatments on mean number of insect larvae per plot at 10 weeks after planting.

There was a significant difference ($p<0.05$) in the mean insect numbers among the four treatments. The Ecoterex and lambda treatments had significantly lower mean insect numbers but were not significantly different from each other (Table 4). The untreated control and Cabaryl were not significantly different from each other. These treatments were significantly different from both the Ecoterex and lambda treatments. There were no significant differences ($p>0.05$) in mean insect numbers among the three varieties at the 10th week (Table 4).

Table 4-Mean number of larvae per plot at week 10 after planting.

	Variety			
Treatment	SC513	PAN53	SC529	LSDvar
Ecoterex	3.33 a	1.00 a	3.00 a	8.426 NS
Lambda	0.00 a	1.00 a	0.00 a	

Untreated	8.67 b	0.00 a	12.00 b	
Carbaryl	7.00 b	6.67 b	8.00 b	
Pvaluetreat	0.017			
Pvaluevar	0.216			
Pvalueint	0.400			
LSDtreat	4.865			
CV%	18.4			

1- Figures followed by the same lowercase letter in the same column are not significantly different from each other at p=0.05.

2- NS= No significant difference at p=0.05

4.1.3 Effect of treatments on mean number of larvae per plot at 11 weeks after planting.

There was a significant difference (p<0.05) in the mean insect numbers among the four treatments. The Ecoterex and lambda treatments had significantly lower mean insect numbers but were not significantly different from each other (Table5). The untreated control and Cabaryl were not significantly different from each other. These treatments were significantly different from both the Ecoterex and lambda treatments. There were no significant differences (p>0.05) in mean insect numbers among the three varieties at the 11th week (Table5).

Table 5-Mean number of insect larvae per plot at week 11 after planting.

	Variety			
Treatment	SC513	PAN53	SC529	LSDvar
Ecoterex	4.33 a	1.00 a	0.67 a	5.048NS
Lambda	2.00 a	2.00 a	1.00 a	
Untreated	9.00 b	2.67 ab	6.33 b	
Cabaryl	8.00 b	5.00 b	9.33 b	
Pvaluetreat	<0.001			

Pvaluevar	0.051
Pvalueint	0.417
LSDtreat	2.914
CV%	70

1- Figures followed by the same lowercase letter in the same column are not significantly different from each other at p=0.05.

2- NS= No significant difference at p=0.05

4.1.4 Effect of treatments on mean number of days to maturity for the three varieties.

There were significant differences (P<0.05) in the number of days to maturity across the three varieties (Table 6). Variety SC513 had the lowest mean number of days to maturity and this was significantly different from variety SC529 which had a mean number of 135 days to maturity (Table 6). Variety PAN 53 had the highest mean number of days to maturity at 150 days and this was significantly different from both SC513 and SC529. There were no significant differences (P>0.05) in the number of days to maturity across the four treatments within each variety (Table 6).

Table 6-Mean number of Days to Maturity for the three varieties.

	Variety			
Treatment	SC513	PAN53	SC529	LSDvar
Ecoterex	130.00 A	150.00 C	135.00 B	1.0
Lambda	130.00 A	150.00 C	135.00 B	
Untreated	130.00 A	150.00 C	135.00 B	
Cabaryl	130.00 A	150.00 C	135.00 B	
Pvaluetreat	1.0			
Pvaluevar	<0.001			

Pvalueint	NS
LSDtreat	NS
CV%	1.0

1- Figures followed by the same uppercase letter in the same row are not significantly different from each other at p=0.05.

2- NS= No significant difference at p=0.05

4.1.5 Effect of treatments on mean leaf size across four treatments for the three varieties.

There were no significant differences in leaf size ($p>0.05$) across the four treatments (Table 7). There were significant differences ($P<0.05$) in leaf size across the three varieties. Variety PAN53 had a significantly larger leaf size compared to varieties SC513 and SC529 which were not significantly different from each other (Table 7).

Table 7-Mean leaf size (cm) leaf length at maturity.

	Variety			
Treatment	SC513	PAN53	SC529	LSDvar
Ecoterex	76.7 A	92.3 B	76.0 A	12.39
Lambda	72.3 A	87.7 B	82.7 B	
Untreated	80.7 AB	87.7 B	75.3 A	
Cabaryl	76.0 A	81.7 A	71.7 A	
Pvaluetreat	0.418			
Pvaluevar	0.001			
Pvalueint	0.481			
LSDtreat	7.15 NS			
CV%	9.2			

1- Figures followed by the same uppercase letter in the same row are not significantly different from each other at p=0.05.

2- NS= No significant difference at p=0.05

4.1.6 Effect of treatments on mean plant height across four treatments for the three varieties.

There was significant difference in mean plant height across the three varieties. There was no significant difference (P>0.05) across the four treatments (Table 8).

Table 8-Mean plant height (cm) at maturity.

	Variety			
Treatment	SC513	PAN53	SC529	LSDvar
Ecoterex	205.0 B	206.7 B	192.3 A	11.26
Lambda	195.0 A	206.7 B	195.0 A	
Untreated	195.0 A	208.3 B	202.3 A	
Cabaryl	196.7 A	205.0 B	195.0 A	
Pvaluetreat	0.680			
Pvaluevar	0.001			
Pvalueint	0.341			
LSDtreat	6.50 NS			
CV%	3.3			

1- Figures followed by the same uppercase letter in the same row are not significantly different from each other at p=0.05.

2- NS= No significant difference at p=0.05

4.1.7 Effect of treatments on mean total number of leaves across four treatments for the three varieties.

There were no significant differences in leaf number (p>0.05) across the four treatments and the three varieties (Table 9). Treatment Ecoterex, Lambda and untreated had no significance difference on each other. Treatment Cabaryl had a slight significance difference from three treatments. On varieties PAN53 had highest numbers of leaves mean as compared to other varieties and followed by SC529 and SC513.

Table 9-Mean total number of leaves per plant at maturity

	Variety			
Treatment	SC513	PAN53	SC529	LSDvar
Ecoterex	15.00	16.33	15.00	1.589 NS
Lambda	15.00	15.67	15.67	
Untreated	15.00	16.00	15.00	
Cabaryl	15.67	15.33	14.00	
Pvaluetreat	0.721			
Pvaluevar	0.066			
Pvalueint	0.406			
LSDtreat	0.917 NS			
CV%	6.2			

NS= No significant difference at p=0.05

4.1.8 Effect of treatments on plant vigor at maturity across four treatments for the three varieties.

There were significant differences in vigor score ($p<0.05$) across the four treatments, Treatments Ecoterex and lambda were not significantly different from each other. Treatments Untreated and Cabaryl were also not significantly different from each other. There were no significant differences ($P>0.05$) in vigor score across the three varieties (Table 10).

Table 10-Plant vigor at maturity measured on a scale of 1-10 with 1 being the highest and 10 being the lowest.

	Variety			
Treatment	SC513	PAN53	SC529	LSDvar
Ecoterex	3.00 a	1.67 a	2.33 a	3.861NS
Lambda	1.67 a	4.33 a	1.00 a	
Untreated	5.67 b	4.00 b	5.67 b	
Cabaryl	6.67 b	3.33 b	3.67 b	
Pvaluetreat	0.027			
Pvaluevar	0.484			
Pvalueint	0.323			
LSDtreat	2.229			
CV%	63.9			

1- Figures followed by the same lowercase letter in the same column are not significantly different from each other at p=0.05.
2- NS= No significant difference at p=0.05

4.1.9 Effect of treatments on mean plant biomass across four treatments for the three varieties.

There were no significant differences in plant biomass (P>0.05) both across the four treatments and across the three varieties (Table 11). Treatment Cabaryl and Ecoterex had no significantly difference on mean plant biomass.

Table 11-Plant biomass in tons per hectare at harvest.

	Variety			
Treatment	SC513	PAN53	SC529	LSDvar
Ecoterex	10.63	12.77	8.23	2.34NS
Lambda	8.90	10.57	11.97	

Untreated	9.23	9.93	8.00
Cabaryl	11.10	11.47	9.53
Pvaluetreat	0.595		
Pvaluevar	0.305		
Pvalueint	0.602		
LSDtreat	2.34NS		
CV%			

4.1.10 Effect of treatments on mean cob quality scores across four treatments for the three varieties.

There were significant differences ($p<0.05$) across both treatments and varieties for the mean cob quality scores (Table 12). Treatment Ecoterex and Lambda were not significantly differently in terms of their means and they recorded lowest means scores. Treatment Untreated and Cabaryl were not significantly different from each other but significantly different from treatments Ecoterex and Lambda. On verities PAN53 had a higher mean cob quality as compare to Sc513 and SC529.

Table 12-Mean Cob Quality scores at harvest measured on a scale of 1 to 5 (with 1 being the best).

	Variety			
Treatment	SC513	PAN53	SC529	LSDvar
Ecoterex	2.00 B a	1.00 A a	2.33 B a	1.287
Lambda	2.67 B a	1.67 A a	1.67 A a	
Untreated	3.33 B b	2.67 A b	3.33 B b	
Cabaryl	4.00 B b	2.67 A b	3.33 A b	
Pvaluetreat	<0.001			
Pvaluevar	0.008			
Pvalueint	0.701			
LSDtreat	0.743			
CV%	29.9			

1- Figures followed by the same lowercase letters in the same column are not significantly different from each other at $p=0.05$.

2- Figures followed by the same uppercase letters in the same row are not significantly different from each other at p=0.05.

4.1.11 Effect of treatments on mean cob size (cm length) scores across four treatments for the three varieties.

There were significant differences ($P<0.05$) in cob size both across the four treatments and across the three varieties (Table 13). Treatments Ecoterex, Lambda and Untreated were not significantly different on mean cob size and Cabaryl was significantly different from other three treatments. On varieties PAN53 recorded the highest mean cob size of 30.67 comparing with two other varieties and variety Sc513 recorded the lowest mean cob size of 23 cm comparing with PAN53 and SC529.

Table 13-Mean cob size measured as cm at harvest.

	Variety					
Treatment	SC513		PAN53		SC529	LSDvar
Ecoterex	25.67	b	30.67	b	25.00	3.942
Lambda	27.00	b	28.33	b	25.67	
Untreated	27.67	b	30.00	b	24.67	
Cabaryl	23.00	a	25.33	a	24.33	
Pvaluetreat	0.026					
Pvaluevar	0.002					
Pvalueint	0.465					
LSDtreat	2.276					
CV%						

1- Figures followed by the same lowercase letter in the same column are not significantly different from each other at p=0.05.

4.1.12 Effect of treatments on mean grain weight (tons/ha) scores across four treatments for the three varieties.

There were no significant differences in mean grain weight (p>0.05) across the four treatment and three varieties (Table 14). Treatment Ecoterex and Lambda there was no significant difference in terms of mean grain weight. Treatment Untreated and Cabaryl there was also no significant difference in terms of mean grain weight. Variety PAN53 had recorded the highest yield of 12.67 tons per hectare when comparing with other two varieties and SC529 recorded the lowest in terms of yield of 9.53 tons per hectare.

Table 14-Mean grain weight in tons per hectare

	Variety			
Treatment	SC513	PAN53	SC529	LSDvar
Ecoterex	11.30	12.67	10.38	3.436NS
Lambda	11.20	12.37	11.43	
Untreated	10.28	10.97	7.37	
Cabaryl	10.83	9.50	9.5	
Pvaluetreat	0.088			
Pvaluevar	0.133			
Pvalueint	0.659			
LSDtreat	1.984 NS			
CV%	19.1			

4.3 Discussion and Interpretation of Results.

4.3.1 Effect of chemical treatments on mean number of larvae per plot at 7 weeks after planting.

There were no significant differences (Pp>0.05) for the mean insect larvae numbers among the four treatments and between the three varieties at week 7 after planting (Table 1). There was no significant interaction between the treatments and the varieties (Table 1). Treatment Ecoterex and Lambda were not significantly different on mean number of larvae per plot. The Cabaryl treatment and Untreated control were not significantly different each other but significantly different from treatment Ecoterex and Lambda. Variety SC529 had the highest mean number of larvae per plot (15). Then SC513 followed with SC529 and Pan53 recorded the lowest mean number of larvae per plot 4. From the study Ecoterex and lambda showed they effectively control the fall armyworm coupled with maize variety with little resistance such as Pan53.

4.3.2 Effect of chemical treatments on mean number of larvae per plot at 8 weeks after planting.

There was a significant difference ($p<0.05$) in the mean insect larvae numbers among the four treatments. The Ecoterex and lambda had significantly lower mean insect larvae numbers but were not significantly different from each other. The untreated control and Cabaryl were not significantly different from each other. The untreated control and Cabaryl were significantly different from both the Ecoterex and treatments. There were no significant differences ($p>0.05$) in mean insect numbers among the three varieties at the 8th week. (Table 2). There was no significant interaction between the treatments and the varieties (Table 2).

4.3.4 Effect of treatments on mean number of larvae per plot at 9 weeks after planting.

There was a significant difference ($p<0.05$) in the mean insect larvae numbers among the four treatments. The Ecoterex and lambda had significantly lower mean insect larvae numbers but were not significantly different from each other. The untreated control and Cabaryl were not significantly different from each other. These treatments were significantly different from both the Ecoterex and lambda treatments. There were no significant differences ($p>0.05$) in mean insect larvae numbers among the three varieties at the 9th week (Table 3). There was no significant interaction between treatments and variety at week 9 (Table 3). There were no significant differences across the three varieties for each treatment (Table 3). Varieties SC529 had the lowest mean number of larvae which was 0.7 and highest was SC513 with 15.7 mean. Variety Pan53 had the medium mean between the two treatments.

4.3.5 Effect of treatments on mean number of insect larvae per plot at 10 weeks after planting.

There was a significant difference ($p<0.05$) in the mean insect numbers among the four treatments. The Ecoterex and lambda treatments had significantly lower mean insect numbers but were not significantly different from each other (Table 4). The untreated control and Cabaryl were not significantly different from each other. These treatments were significantly different from both the Ecoterex and lambda treatments. There were no significant differences ($p>0.05$) in mean insect numbers among the three varieties at the 10th week (Table 4).

4.3.6 Effect of treatments on mean number of larvae per plot at 11 weeks after planting.

There was a significant difference ($p<0.05$) in the mean insect numbers among the four treatments. The Ecoterex and lambda treatments had significantly lower mean insect numbers but were not significantly different from each other (Table5). The untreated control and Cabaryl were not significantly different from each other. These treatments were significantly different from both the Ecoterex and lambda treatments. There were no significant differences ($p>0.05$) in mean insect numbers among the three varieties at the 11th week (Table5).

4.3.7 Effect of treatments on mean number of days to maturity for the three varieties.

There were significant differences ($P<0.05$) in the number of days to maturity across the three varieties (Table 6). Variety SC513 had the lowest mean number of days to maturity and this was significantly different from variety SC529 which had a mean number of 135 days to maturity (Table 6). Variety PAN 53 had the highest mean number of days to maturity at 150 days and this was significantly different from both SC513 and SC529. There were no significant differences ($P>0.05$) in the number of days to maturity across the four treatments within each variety (Table 6). Mean number of days to maturity are genetically controlled by variety and ecological regions in Zimbabwe according to Seed Co Seed Product Manual Good Agronomic Practices and Crop Section.

4.3.8 Effect of treatments on mean leaf size across four treatments for the three varieties.

There were no significant differences in leaf size ($p>0.05$) across the four treatments (Table 7). There were significant differences ($P<0.05$) in leaf size across the three varieties. Variety PAN53 had a significantly larger leaf size compared to varieties SC513 and SC529 which were not significantly different from each other (Table 7). The maize leaf size is genetically controlled and the variety plays a pivotal role in controlling the number of leaves per plant according to Seed Co Seed Product Manual Good Agronomic Practices and Crop Section.

4.3.9 Effect of treatments on mean plant height across four treatments for the three varieties.

There was significant difference in mean plant height across the three varieties. There was no significant difference ($P>0.05$) across the four treatments (Table 8). Varieties had the highest mean plant height 208.3cm, followed by SC513 which had 205.0cm and lastly SC529 202. 3cm. Maize plant height is controlled genetically due to variety and also soil nutrition plays a critical role in plant height. This is supported by Okumura *et al*., (2011) and Santos *et al*., (2002) nutrients increases plant growth (nitrogen).

4.3.10 Effect of treatments on mean total number of leaves across four treatments for the three varieties.

There were no significant differences in leaf number ($p>0.05$) across the four treatments and the three varieties (Table 9). Treatment Ecoterex, Lambda and untreated had no significance difference on each other. Treatment Cabaryl had a slight significance difference from three treatments. On varieties PAN53 had highest numbers of leaves mean as compared to other varieties such as SC529 and SC513.The number of leaves are controlled genetically and also variety contribute. Nutrition plays a pivotal role in the number of leaves per plant or per variety. This was supported by Okumura *et al*., (2011) and Santos *et al*., (2002) nutrition increases the number of leaves per plant and leaf area. The number of leaves per plant can be significantly influenced by the plant variety.

4.3.11 Effect of treatments on plant vigor at maturity across four treatments for the three varieties.

There were significant differences in vigor score ($p<0.05$) across the four treatments, Treatments Ecoterex and lambda were not significantly different from each other. Treatments Untreated and Cabaryl were also not significantly different from each other. There were no significant differences ($P>0.05$) in vigor score across the three varieties (Table 10). Treatment Ecoterex and lambda were not significantly different from each other. Untreated and Cabaryl were not significantly different but significantly different from Ecoterex and lambda treatments. Plant vigor it’s controlled by plant nutrition and variety this was supported by Mohamed & Mahmoud, (2016).

4.3.12 Effect of treatments on mean plant biomass across four treatments for the three varieties.

There were no significant differences in plant biomass (P>0.05) both across the four treatments and across the three varieties (Table 11). Treatment Cabaryl and Ecoterex were not significantly difference on mean plant biomass. Treatment Lambda and Untreated had no significant difference on their means but were significantly different from treatment Ecoterex and Cabaryl. Variety PAN53 with 12.77 had the highest mean plant biomass in tonnes per hectare at harvest as compared with SC529 with mean of 11.97 tons per hectare of biomass and SC513 with the lowest mean plant biomass of 8.90 tons per hectare.

4.3.13 Effect of treatments on mean cob quality scores across four treatments for the three varieties.

There was significant difference (p<0.05) across both treatments and varieties for the mean cob quality scores (Table 12). Treatment Ecoterex and Lambda were not significantly differently in terms of their means and they recorded lowest means scores. Treatment Untreated and Cabaryl were not significantly different from each other but significantly different from treatments Ecoterex and Lambda. On verities PAN53 had a higher mean cob quality as compare to SC513 and SC529.C

4.3.14 Effect of treatments on mean cob size (cm length) scores across four treatments for the three varieties.

There were significant differences (P<0.05) in cob size both across the four treatments and across the three varieties (Table 13). Treatments Ecoterex, Lambda and Untreated were not significantly different on mean cob size and Cabaryl was significantly different from other three treatments. On varieties PAN53 recorded the highest mean cob size of 30.67 comparing with two other varieties and variety Sc513 recorded the lowest mean cob size of 23 cm comparing with PAN53 and SC529.The cob size normally depends with the variety and its genetically controlled.

4.3.15 Effect of treatments on mean grain weight (tons/ha) scores across four treatments for the three varieties.

There were no significant differences in mean grain weight (p>0.05) across the four treatment and three varieties (Table 14). Treatment Ecoterex and Lambda there was no significant difference in terms of mean grain weight. Treatment Untreated and Cabaryl there was also no significant difference in terms of mean grain weight. Variety PAN53 had recorded the highest yield of 12.67 tons per hectare when comparing with other two varieties and SC529 recorded the lowest in terms of yield of 9.53 tonnes per hectare. The grain weight is influenced by variety and is genetically controlled coupled with nutrition applied or in the soil. Planting and planting time is another factor which contributes to grain weight. Late plantings yield less as compared to early plantings according to Seed Co Seed Product Manual Good Agronomic Practices and Control section.

CHAPTER 5 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This study was initiated to assess and understand the impact of fall armyworm on maize production in Seke district. The objectives of this study were to clarify the economic impact of fall armyworm on maize production in Seke District for small holder farmers. The study was aimed at finding the low cost ways of controlling maize fall armyworm using chemicals such as Ecoterex, lambda cyahatholine and Cabaryl. These chemicals were sprayed weekly from 4 weeks where the effects of fall armyworm started showing visible signs on maize. The chemicals Ecoterex and lambda cyahatholine showed significant results in controlling the fall armyworm in the three maize varieties used in the experiment.

5.2 Discussion

There was clear lower mean number of larvae per plot from 7 to 11 weeks during the treatment phase for Ecoterex and lambda cyahatholine treatments. Cabaryl had a higher mean number of larvae for the three maize varieties used in the study which shows its efficacy was questionable. Variety PAN53 showed some degree of resistance to fall armyworm because normally had lower mean number of larvae per plot as compared to other varieties, even though numerically the different were not statistically significant. Varieties SC529 and SC513 showed little resistance to fall armyworm and per plot these two varieties showed higher mean number of larvae per plot. Consistent with findings from other researchers, the results showed that fall armyworm had a significant negative impact on maize. There were no significant differences in mean grain weight ($p>0.05$) across the four treatment and three varieties (Table 14). Variety PAN53 had recorded the highest yield of 12.67 tons per hectare when comparing with other two varieties and SC529 recorded the lowest in terms of yield of 9.53 tonnes per hectare.

5.3 Conclusions

The study showed that there was no significant difference between the Ecoterex and lambda Cyhalothrin treatments in the control of fall armyworm. This implies that farmers can safely use both Ecoterex and lambda cyhalothrin preferably in a rotational sequence for the control of fall armyworm. The Cabaryl treatment was not significantly different from the untreated control in the suppression of fall armyworm. Even though Cabaryl is recommended for the control of other armyworm species such as the African armyworm (*Spodoptera exempta*), it is clear from this study that Cabaryl is not effective against fall armyworm (*Spodoptera frugiperda*). The study also showed that there was no significant difference across the three maize varieties in terms of susceptibility to fall armyworm attack. The three varieties namely SC 513, SC529 and PAN 53 were equally susceptible to FAW attack. There were significant differences ($P<0.05$) in the number of days to maturity across the three varieties. Variety SC513 had the lowest mean number of days to maturity and this was significantly different from variety SC529 which had a mean number of 135 days to maturity. The time to maturity was not influenced by the chemical treatments that were used.

5.4 Implications

The results from this study have showed that smallholder farmers can use Ecoterex and lambda cyhalothrin in the control of FAW. The lack of significant differences in the performance of the three medium maturity maize varieties implies that farmers in Seke district can plant any of the three varieties without the risk of having aggravated crop attack emanating from FAW. This emanates from the fact that all three varieties were equally susceptible to attack by FAW. This implies that farmers should be continuously imparted with information on both current and new technologies, products and equipment they use every day for the success of their business. The study will help agriculture policy makers in recommending the appropriate chemicals for use by farmers in the control of FAW.

5.5 Recommendations

Results from the study clearly showed that the chemicals Ecoterex and lambda cyhalothrin were effective in the control of FAW. Farmers are therefore encouraged to use these chemicals for the control of FAW. The chemicals should preferably be used in a rotation so as to reduce changes of pesticide resistance in the FAW populations. Maize production farmers in Zimbabwe are recommended to make sure they control the FAW using chemicals that have been tested and approved for use against FAW in an integrated pest management package.

5.6 Suggestions for Further Research

A research gap exists on the impact of natural enemies on the control of the FAW. In the current study, no natural enemies of FAW were detected. There is therefore need to study the spectrum of natural enemies of FAW in the Seke District. The second aspect that also needs further research is the impact of the chemicals Ecoterex and lambda cyhalothrin on the survival of beneficial natural enemies. In a bid to advance the cause of Integrated Pest Management, farmers are encouraged to use synthetic pesticides that have the least impact on the survival and proliferation of natural enemies. The researcher recommends that the experiments for adaptability of natural enemies of the recommended chemicals, namely Ecoterex and lambda cyhalothrin must be carried out at different sites and different seasons. More conclusive results will be achieved if these trials are conducted at another two sites with different agro-ecological conditions in different climatic regions. Research on host plant resistance, including genetically modified plants, and chemical control is advancing in the private sector and international research institutes. Most of these new technologies are not accessible by smallholder farmers. Large knowledge gaps exist for the use of biological control, plant chemical ecology and the use of locally available substances to deter or kill FAW. Very little research is being carried out on the use of these methods by smallholders.

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APPENDICES

Genstat 5 Release 3.2 (PC/Windows NT)

Appendix 1. Variate: Plant Biomass

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum					
variety	2	19.309	9.654		
Rep.*Units* stratum					
Trtment	3	15.799	5.266	0.64	0.595
Trtment. Variety	6	37.771	6.295	0.77	0.602
Residual	24	196.740	8.197		
Total	35	269.619			

***** Tables of means *****

Variate: Biomass

Grand mean 10.19

Trtment	1.00	2.00	3.00	4.00
	10.54	10.48	9.06	10.70

variety	1.00	2.00	3.00
	9.97	11.18	9.43

Trtment variety	1.00	2.00	3.00
1.00	10.63	12.77	8.23
2.00	8.90	10.57	11.97
3.00	9.23	9.93	8.00
4.00	11.10	11.47	9.53

*** Standard errors of differences of means ***

Table	Trtment	variety	Trtment variety
rep.	9	12	3
d.f.	24	*	*
s.e.d.	1.350	*	*

Except when comparing means with the same level(s) of variety 2.338

Appendix 2. Variate: Cob size

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum					
variety	2	87.389	43.694		
Rep.*Units* stratum					
Trtment	3	60.222	20.074	3.67	0.026
Trtment. Variety	6	31.944	5.324	0.97	0.465
Residual	24	131.333	5.472		
Total	35	310.889			

***** Tables of means *****

Variate: Cob size

Grand mean 26.44

Trtment	1.00	2.00	3.00	4.00
	27.11	27.00	27.44	24.22

variety	1.00	2.00	3.00
	25.83	28.58	24.92

Trtment variety	1.00	2.00	3.00
1.00	25.67	30.67	25.00
2.00	27.00	28.33	25.67
3.00	27.67	30.00	24.67
4.00	23.00	25.33	24.33

*** Standard errors of means ***

Table	Trtment	variety	Trtment variety
rep.	9	12	3
d.f.	24	*	*

```
e.s.e.               0.780          *           *
Except when comparing means with the same level(s) of
 variety                                    1.351

*** Standard errors of differences of means ***

Table              Trtment     variety     Trtment
                                           variety
rep.                     9          12           3
d.f.                    24           *           *
s.e.d.               1.103           *           *
Except when comparing means with the same level(s) of
 variety                                    1.910

*** Least significant differences of means ***

Table              Trtment     variety     Trtment
                                           variety
rep.                     9          12           3
d.f.                    24           *           *
l.s.d.               2.276           *           *
Except when comparing means with the same level(s) of
 variety                                    3.942


***** Stratum standard errors and coefficients of variation *****

Variate: Cob size

Stratum                  d.f.          s.e.         cv%

Rep                         0             *           *
Rep.*Units*                24         2.339         8.8
```

Appendix 3. Variate: Grain weight

```
Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

Rep stratum
variety                    2     18.393      9.196

Rep.*Units* stratum
Trtment                    3     30.514     10.171    2.45 0.088
Trtment. Variety6     17.218      2.870    0.69 0.659
Residual                  24     99.760      4.157

Total                     35    165.885

***** Tables of means *****

Variate: Grain weight
```

```
Grand mean 10.65

  Trtment     1.00     2.00     3.00     4.00
             11.45    11.67     9.54     9.96

  variety     1.00     2.00     3.00
             10.90    11.38     9.68

Trtment variety     1.00     2.00     3.00
     1.00          11.30    12.67    10.38
     2.00          11.20    12.37    11.43
     3.00          10.28    10.97     7.37
     4.00          10.83     9.50     9.53


*** Standard errors of means ***

Table              Trtment     variety     Trtment
                                           variety
rep.                     9          12           3
d.f.                    24           *           *
e.s.e.               0.680           *           *
Except when comparing means with the same level(s) of
 variety                                     1.177

*** Standard errors of differences of means ***

Table              Trtment     variety     Trtment
                                           variety
rep.                     9          12           3
d.f.                    24           *           *
s.e.d.               0.961           *           *
Except when comparing means with the same level(s) of
 variety                                     1.665

*** Least significant differences of means ***

Table              Trtment     variety     Trtment
                                           variety
rep.                     9          12           3
d.f.                    24           *           *
l.s.d.               1.984           *           *
Except when comparing means with the same level(s) of
 variety                                     3.436


***** Stratum standard errors and coefficients of variation *****

Variate: Grain weight

Stratum                   d.f.          s.e.         cv%

Rep                          0             *           *
Rep.*Units*                 24         2.039        19.1
```

Appendix 4. Variate: Leaf size

***** Analysis of variance *****

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum					
variety	2	953.39	476.69		
Rep.*Units* stratum					
Trtment	3	159.22	53.07	0.98	0.418
Trtment. Variety6	306.61	51.10	0.95 0.481		
Residual	24	1296.67	54.03		
Total	35	2715.89			

***** Tables of means *****

Variate: Leafsize

Grand mean 80.1

Trtment	1.00	2.00	3.00	4.00
	81.7	80.9	81.2	76.4

variety	1.00	2.00	3.00
	76.4	87.3	76.4

Trtment variety	1.00	2.00	3.00
1.00	76.7	92.3	76.0
2.00	72.3	87.7	82.7
3.00	80.7	87.7	75.3
4.00	76.0	81.7	71.7

*** Standard errors of means ***

Table	Trtment	variety	Trtment variety
rep.	9	12	3
d.f.	24	*	*
e.s.e.	2.45	*	*
Except when comparing means with the same level(s) of variety			4.24

*** Standard errors of differences of means ***

Table	Trtment	variety	Trtment variety
rep.	9	12	3
d.f.	24	*	*
s.e.d.	3.46	*	*
Except when comparing means with the same level(s) of variety			6.00

*** Least significant differences of means ***

Table	Trtment	variety	Trtment variety
rep.	9	12	3
d.f.	24	*	*
l.s.d.	7.15	*	*
Except when comparing means with the same level(s) of variety			12.39

***** Stratum standard errors and coefficients of variation *****

Variate: Leafsize

Stratum	d.f.	s.e.	cv%
Rep	0	*	*
Rep.*Units*	24	7.35	9.2

Appendix 5. Variate: Maturity

***** Analysis of variance *****

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum					
variety	2	2600.000	1300.000		
Rep.*Units* stratum					
Trtment	3	0.000	0.000		
Trtment. Variety 6	0.000	0.000			
Residual	24	0.000	0.000		

Total	35	2600.000

***** Tables of means *****

Variate: Maturity

Grand mean 138.33

Trtment	1.00	2.00	3.00	4.00
	138.33	138.33	138.33	138.33

variety	1.00	2.00	3.00
	130.00	150.00	135.00

Trtment variety	1.00	2.00	3.00
1.00	130.00	150.00	135.00
2.00	130.00	150.00	135.00
3.00	130.00	150.00	135.00
4.00	130.00	150.00	135.00

*** Standard errors of means ***

Table	Trtment	variety	Trtment variety
rep.	9	12	3
d.f.	*	*	*
e.s.e.	0.000	*	*

*** Standard errors of differences of means ***

Table	Trtment	variety	Trtment variety
rep.	9	12	3
d.f.	*	*	*
s.e.d.	0.000	*	*

*** Least significant differences of means ***

Table	Trtment	variety	Trtment variety
rep.	9	12	3
d.f.	*	*	*
l.s.d.	0.000	*	*

***** Stratum standard errors and coefficients of variation *****

Variate: Maturity

Stratum	d.f.	s.e.	cv%
Rep	0	*	*

Rep.*Units*	24	0.000	0.0

Appendix 6. Variate: Plant height

***** Analysis of variance *****

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum					
variety	2	759.50	379.75		
Rep.*Units* stratum					
Trtment	3	68.08	22.69	0.51	0.680
Trtment. Variety	6	321.17	53.53	1.20	0.341
Residual	24	1072.00	44.67		
Total	35	2220.75			

***** Tables of means *****

Variate: Plant height

Grand mean 200.3

Trtment	1.00	2.00	3.00	4.00
	201.3	198.9	201.9	198.9

variety	1.00	2.00	3.00
	197.9	206.7	196.2

Trtment variety	1.00	2.00	3.00
1.00	205.0	206.7	192.3
2.00	195.0	206.7	195.0
3.00	195.0	208.3	202.3
4.00	196.7	205.0	195.0

*** Standard errors of means ***

Table	Trtment	variety	Trtment variety
rep.	9	12	3
d.f.	24	*	*
e.s.e.	2.23	*	*
Except when comparing means with the same level(s) of variety			3.86

*** Standard errors of differences of means ***

Table	Trtment	variety	Trtment variety
rep.	9	12	3
d.f.	24	*	*
s.e.d.	3.15	*	*
Except when comparing means with the same level(s) of variety			5.46

*** Least significant differences of means ***

Table	Trtment	variety	Trtment variety
rep.	9	12	3
d.f.	24	*	*
l.s.d.	6.50	*	*
Except when comparing means with the same level(s) of variety			11.26

***** Stratum standard errors and coefficients of variation *****

Variate: Plant height

Stratum	d.f.	s.e.	cv%
Rep	0	*	*
Rep.*Units*	24	6.68	3.3

Appendix 7. Variate: Quality

***** Analysis of variance *****

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum					
variety	2	6.2222	3.1111		
Rep.*Units* stratum					
Trtment	3	16.4444	5.4815	9.40	<.001
Trtment. Variety	6	2.2222	0.3704	0.63	0.701
Residual	24	14.0000	0.5833		

```
Total                     35    38.8889


***** Tables of means *****

Variate: Quality

Grand mean 2.56

  Trtment     1.00     2.00     3.00     4.00
              1.78     2.00     3.11     3.33

  variety     1.00     2.00     3.00
              3.00     2.00     2.67

Trtment variety     1.00     2.00     3.00
     1.00              2.00     1.00     2.33
     2.00              2.67     1.67     1.67
     3.00              3.33     2.67     3.33
     4.00              4.00     2.67     3.33


*** Standard errors of means ***

Table              Trtment     variety     Trtment
                                           variety
rep.                     9          12           3
d.f.                    24           *           *
e.s.e.               0.255           *           *
Except when comparing means with the same level(s) of
 variety                                     0.441

*** Standard errors of differences of means ***

Table              Trtment     variety     Trtment
                                           variety
rep.                     9          12           3
d.f.                    24           *           *
s.e.d.               0.360           *           *
Except when comparing means with the same level(s) of
 variety                                     0.624

*** Least significant differences of means ***

Table              Trtment     variety     Trtment
                                           variety
rep.                     9          12           3
d.f.                    24           *           *
l.s.d.               0.743           *           *
Except when comparing means with the same level(s) of
 variety                                     1.287


***** Stratum standard errors and coefficients of variation *****
```

Variate: Quality

Stratum	d.f.	s.e.	cv%
Rep	0	*	*
Rep.*Units*	24	0.764	29.9

Appendix 8. Variate: Total leaf

***** Analysis of variance *****

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum					
variety	2	5.3889	2.6944		
Rep.*Units* stratum					
Trtment	3	1.1944	0.3981	0.45	0.721
Trtment. Variety	6	5.7222	0.9537	1.07	0.406
Residual	24	21.3333	0.8889		
Total	35	33.6389			

***** Tables of means *****

Variate: Total leaf

Grand mean 15.31

Trtment	1.00	2.00	3.00	4.00
	15.44	15.44	15.33	15.00

variety	1.00	2.00	3.00
	15.17	15.83	14.92

Trtment variety	1.00	2.00	3.00
1.00	15.00	16.33	15.00
2.00	15.00	15.67	15.67
3.00	15.00	16.00	15.00
4.00	15.67	15.33	14.00

*** Standard errors of means ***

Table	Trtment	variety	Trtment

			variety
rep.	9	12	3
d.f.	24	*	*
e.s.e.	0.314	*	*

Except when comparing means with the same level(s) of
variety 0.544

*** Standard errors of differences of means ***

Table	Trtment	variety	Trtment variety
rep.	9	12	3
d.f.	24	*	*
s.e.d.	0.444	*	*

Except when comparing means with the same level(s) of
variety 0.770

*** Least significant differences of means ***

Table	Trtment	variety	Trtment variety
rep.	9	12	3
d.f.	24	*	*
l.s.d.	0.917	*	*

Except when comparing means with the same level(s) of
variety 1.589

***** Stratum standard errors and coefficients of variation *****

Variate: Total leaf

Stratum	d.f.	s.e.	cv%
Rep	0	*	*
Rep.*Units*	24	0.943	6.2

Appendix 9. Variate: Vigor

***** Analysis of variance *****

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum					
variety	2	8.167	4.083		
Rep.*Units* stratum					
Trtment	3	57.639	19.213	3.66	0.027
Trtment. Variety	6	38.944	6.491	1.24	0.323
Residual	24	126.000	5.250		

```
Total                     35    230.750


***** Tables of means *****

Variate: Vigor

Grand mean 3.58

  Trtment     1.00     2.00     3.00     4.00
              2.33     2.33     5.11     4.56

  variety     1.00     2.00     3.00
              4.25     3.33     3.17

Trtment variety     1.00     2.00     3.00
     1.00              3.00     1.67     2.33
     2.00              1.67     4.33     1.00
     3.00              5.67     4.00     5.67
     4.00              6.67     3.33     3.67


*** Standard errors of means ***

Table              Trtment     variety     Trtment
                                           variety
rep.                     9          12           3
d.f.                    24           *           *
e.s.e.               0.764           *           *
Except when comparing means with the same level(s) of
 variety                                     1.323

*** Standard errors of differences of means ***

Table              Trtment     variety     Trtment
                                           variety
rep.                     9          12           3
d.f.                    24           *           *
s.e.d.               1.080           *           *
Except when comparing means with the same level(s) of
 variety                                     1.871

*** Least significant differences of means ***

Table              Trtment     variety     Trtment
                                           variety
rep.                     9          12           3
d.f.                    24           *           *
l.s.d.               2.229           *           *
Except when comparing means with the same level(s) of
 variety                                     3.861
```

***** Stratum standard errors and coefficients of variation *****

Variate: Vigor

Stratum	d.f.	s.e.	cv%
Rep	0	*	*
Rep.*Units*	24	2.291	63.9

Appendix 10. Variate: wk7

***** Analysis of variance *****

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum					
variety	2	70.22	35.11		
Rep.*Units* stratum					
Trtment	3	271.22	90.41	2.57	0.078
Trtment. Variety	6	108.44	18.07	0.51	0.792
Residual	24	844.67	35.19		
Total	35	1294.56			

***** Tables of means *****

Variate: wk7

Grand mean 8.61

Trtment	1.00	2.00	3.00	4.00
	6.44	5.56	12.33	10.11

variety	1.00	2.00	3.00
	10.50	7.17	8.17

Trtment variety	1.00	2.00	3.00
1.00	10.00	4.00	5.33
2.00	7.00	7.00	2.67
3.00	12.00	10.00	15.00
4.00	13.00	7.67	9.67

*** Standard errors of differences of means ***

Table	Trtment	variety	Trtment variety
rep.	9	12	3
d.f.	24	*	*
s.e.d.	2.797	*	*

Except when comparing means with the same level(s) of
variety 4.844

Appendix 11. Variate: wk8

***** Analysis of variance *****

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum					
variety	2	214.89	107.44		
Rep.*Units* stratum					
Trtment	3	589.42	196.47	3.52	0.030
Trtment. Variety	6	295.33	49.22	0.88	0.522
Residual	24	1338.00	55.75		
Total	35	2437.64			

***** Tables of means *****

Variate: wk8

Grand mean 9.7

Trtment	1.00	2.00	3.00	4.00
	5.4	5.9	14.2	13.2

variety	1.00	2.00	3.00
	13.1	8.6	7.4

Trtment variety	1.00	2.00	3.00
1.00	9.7	3.0	3.7
2.00	5.7	11.0	1.0
3.00	16.7	11.0	15.0
4.00	20.3	9.3	10.0

*** Standard errors of means ***

Table	Trtment	variety	Trtment variety
rep.	9	12	3
d.f.	24	*	*
e.s.e.	2.49	*	*
Except when comparing means with the same level(s) of			
variety			4.31

*** Standard errors of differences of means ***

Table	Trtment	variety	Trtment variety
rep.	9	12	3
d.f.	24	*	*
s.e.d.	3.52	*	*
Except when comparing means with the same level(s) of			
variety			6.10

*** Least significant differences of means ***

Table	Trtment	variety	Trtment variety
rep.	9	12	3
d.f.	24	*	*
l.s.d.	7.26	*	*
Except when comparing means with the same level(s) of			
variety			12.58

***** Stratum standard errors and coefficients of variation *****

Variate: wk8

Stratum	d.f.	s.e.	cv%
Rep	0	*	*
Rep.*Units*	24	7.47	77.0

Appendix 12. Variate: WK9

***** Analysis of variance *****

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum					
variety	2	21.06	10.53		
Rep.*Units* stratum					
Trtment	3	1029.19	343.06	7.61	<.001
Trtment. Variety	6	336.06	56.01	1.24	0.320
Residual	24	1081.33	45.06		

```
Total                     35    2467.64


* MESSAGE: the following units have large residuals.

Rep 2.00 *units* 11           17.3   s.e. 5.5


***** Tables of means *****

Variate: WK9

Grand mean 9.3

  Trtment     1.00     2.00     3.00     4.00
               3.7      4.8     16.7     12.1

  variety     1.00     2.00     3.00
              10.3      9.1      8.5

Trtment variety     1.00     2.00     3.00
     1.00              7.3      2.3      1.3
     2.00              3.3     10.3      0.7
     3.00             15.0     14.0     21.0
     4.00             15.7      9.7     11.0


*** Standard errors of means ***

Table             Trtment     variety     Trtment
                                          variety
rep.                    9          12           3
d.f.                   24           *           *
e.s.e.               2.24           *           *
Except when comparing means with the same level(s) of
 variety                                     3.88

*** Standard errors of differences of means ***

Table             Trtment     variety     Trtment
                                          variety
rep.                    9          12           3
d.f.                   24           *           *
s.e.d.               3.16           *           *
Except when comparing means with the same level(s) of
 variety                                     5.48

*** Least significant differences of means ***

Table             Trtment     variety     Trtment
                                          variety
rep.                    9          12           3
d.f.                   24           *           *
l.s.d.               6.53           *           *
```

Except when comparing means with the same level(s) of
variety 11.31

***** Stratum standard errors and coefficients of variation *****

Variate: WK9

Stratum	d.f.	s.e.	cv%
Rep	0	*	*
Rep.*Units*	24	6.71	72.1

Appendix 13. Variate: WK10

***** Analysis of variance *****

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum					
variety	2	82.06	41.03		
Rep.*Units* stratum					
Trtment	3	309.56	103.19	4.13	0.017
Trtment. Variety6	162.61	27.10	1.08 0.400		
Residual	24	600.00	25.00		
Total	35	1154.22			

* MESSAGE: the following units have large residuals.

Rep 2.00 *units* 11 13.33 s.e. 4.08

***** Tables of means *****

Variate: WK10

Grand mean 4.22

Trtment	1.00	2.00	3.00	4.00
	2.44	0.33	6.89	7.22

variety	1.00	2.00	3.00
	4.75	2.17	5.75

Trtment variety	1.00	2.00	3.00
1.00	3.33	1.00	3.00
2.00	0.00	1.00	0.00
3.00	8.67	0.00	12.00

4.00	7.00	6.67	8.00

*** Standard errors of means ***

Table	Trtment	variety	Trtment variety
rep.	9	12	3
d.f.	24	*	*
e.s.e.	1.667	*	*
Except when comparing means with the same level(s) of			
variety			2.887

*** Standard errors of differences of means ***

Table	Trtment	variety	Trtment variety
rep.	9	12	3
d.f.	24	*	*
s.e.d.	2.357	*	*
Except when comparing means with the same level(s) of			
variety			4.082

*** Least significant differences of means ***

Table	Trtment	variety	Trtment variety
rep.	9	12	3
d.f.	24	*	*
l.s.d.	4.865	*	*
Except when comparing means with the same level(s) of			
variety			8.426

***** Stratum standard errors and coefficients of variation *****

Variate: WK10

Stratum	d.f.	s.e.	cv%
Rep	0	*	*
Rep.*Units*	24	5.000	118.4

Appendix 14. Variate: WK11

***** Analysis of variance *****

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum					
variety	2	60.222	30.111		

```
Rep.*Units* stratum
Trtment                     3    225.000     75.000    8.36  <.001
Trtment. Variety            6     56.667      9.444    1.05 0.417
Residual                   24    215.333      8.972

Total                      35    557.222


***** Tables of means *****

Variate: WK11

Grand mean 4.28

  Trtment     1.00     2.00     3.00     4.00
              2.00     1.67     6.00     7.44

  variety     1.00     2.00     3.00
              5.83     2.67     4.33

Trtment variety     1.00     2.00     3.00
     1.00              4.33     1.00     0.67
     2.00              2.00     2.00     1.00
     3.00              9.00     2.67     6.33
     4.00              8.00     5.00     9.33


*** Standard errors of means ***

Table              Trtment     variety     Trtment
                                           variety
rep.                     9          12           3
d.f.                    24           *           *
e.s.e.               0.998           *           *
Except when comparing means with the same level(s) of
 variety                                     1.729

*** Standard errors of differences of means ***

Table              Trtment     variety     Trtment
                                           variety
rep.                     9          12           3
d.f.                    24           *           *
s.e.d.               1.412           *           *
Except when comparing means with the same level(s) of
 variety                                     2.446

*** Least significant differences of means ***

Table              Trtment     variety     Trtment
                                           variety
rep.                     9          12           3
d.f.                    24           *           *
```

```
l.s.d.               2.914           *            *
Except when comparing means with the same level(s) of
 variety                                      5.048


***** Stratum standard errors and coefficients of variation *****

Variate: WK11

Stratum                        d.f.          s.e.         cv%

Rep                               0             *            *
Rep.*Units*                      24         2.995         70.0
```