

**Effects Of Maize Variety and Planting Date on Susceptibility to Fall Armyworm  
*Spodoptera frugiperda* (JE Smith); Lepidoptera Noctuidae Attack.**

**A dissertation submitted in partial fulfilment of the requirements for the Master of  
Science Degree in Food Security and Sustainable Agriculture**

**(Production)**

**Bindura University Of Science Education**



**Faculty of Agriculture and Environmental Science**

**Department of Agricultural Economics, Education and Extension**

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Submitted: May 2019

**RELEASE FORM**

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Master of Science Degree in Food Security and Sustainable Agriculture

Effects Of Maize Variety And Planting Date On Susceptibility To Fall Armyworm  
(Spodoptera frugiperda) Attack.

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## **APPROVAL FORM**

The undersigned certified that they have supervised and recommended to Bindura University of Science Education for acceptance of dissertation entitled “Effects Of Maize Variety And Planting Date On Susceptibility To Fall Armyworm (*Spodoptera frugiperda*) Attack” in partial fulfilment of a Master of Science Degree in Food Security and Sustainable Agriculture

DR R Mandumbu

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Date:

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## **DECLARATION**

I hereby declare that the research project entitled “ Effects of Maize Variety And Planting Date on Susceptibility To Fall Armyworm *Spodoptera frugiperda* (JE Smith);Lepidoptera Noctuidae Attack Submitted to Bindura University Of Science Education , Department of Agricultural Economics, Education and Extension is a record of an original work done by me under the guidance and supervision of DR Ronald Mandumbu and this work is submitted in partial fulfilment of the requirements for the award of a Master of Science Degree in Food Security and Sustainable Agriculture. The results embodied in this thesis have not been submitted to any University or Institute for the award of any degree or Diploma.

Leonard Nyabanga

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Signature\_\_\_\_\_

Date: \_\_\_\_\_

## **DEDICATION**

This Research Project is Dedicated to my last born Tanatswa Nyabanga

## **ACKNOWLEDGEMENTS**

I would like to express my utmost thanks and appreciation to Seed co Zimbabwe and Tocek Investments for their support with seed resources for this experiment. Special thanks goes to Mr J Bhasera and Mr D Myers and my supervisor Doc R Mandumbu for holding my hand and guiding me throughout the entire period of the research project. I also want to thank my friends and colleagues, Peter Makiwa and B Sibanda for their constant encouragement and guidance in many aspects of the project. I also would want to thank the following for their invaluable effort in taking care of the agronomic aspects of the research trial, R Mukuwe, B. Gapare. The project took too much valuable family time and resources and therefore I would like to thank m

my family for enduring the pain of missing me due to project commitments.

## **ABSTRACT**

Fall armyworm (FAW) *Spodoptera frugiperda*, (J E Smith) has been devastating to Zimbabwe's agriculture with losses sometimes getting to 100 % and yet there are no confirmed means of managing the pest. The objectives of the experiment were to determine the effect of maize variety and planting date on FAW attack.

In an effort to find a solution to the problem a 3x4 factorial experiment was set up in completely randomized block design to determine the effect of maize variety and planting dates on fall armyworm attack in Mashonaland East province of Zimbabwe. Four commercial maize hybrids (commonly planted in Zimbabwe) were planted over three planting dates. The planting dates were early planting (15 Nov), mid season, (15 Dec), and late planting, (28 December). Leaf damage score and number of plants affected were recorded on a fortnightly basis for maize stages V5,V8, VT and R5 while average exit holes(AEH),kernel average score (KAS), yield(t/ha) and discard % were measured at R5 stage. The experiment was under natural FAW infestation and was established at a site where pest abundance was high. Leaf damage and kernel score were evaluated using the Davies scale.

The effect of maize variety was not significant ( $p>0.05$ ) on all the measured data. Time of planting was significant for all observed data ( $p>0.05$ ) except for exit holes. The interaction of planting dates and maize variety was not significant on all observed data.

Early planting had the least damage on all observed data and had the highest yield compared to mid season and late planted crops. Leaf damage score for early planting at maturity stage (R5 stage) was 1.57 compared to 4.63 for Late planting. Kernel damage for early planting was 1.27 compared to 4.37 for late planting. Observed data on yield indicated 10% percent discard (as a result of FAW damage and subsequent fungal infections) compared to 20.93% and 30.64% for mid season and late planting respectively. Early planting had the highest yield of 3.93t/ha compared to 1.77 t/ha for late planting.

The results obtained indicated that early planting can be used as the best site specific cultural control measure for FAW in areas where the pest has a migratory habit during cold winters.

### **Key words:**

- 1.Endemic pest
- 2.Early planting
3. Mid season planting
4. Late planting

## LIST OF ABBREVIATIONS

1. AEH	Average exit holes
2. ALS	Average leaf score
3. CABI	Centre for Agricultural Biosciences International
4. CGIAR	Consultative Group For International Agriculture Research
5. CIMMYT	International Maize and Wheat improvement Centre
6. Disc%	Discard percent
7. E	Early Planting
8. IMF	International Monetary Fund
9. KAS	Kernel Average Score
10. L	late planting
11. M	Mid season planting
12. OECD	Organization for Economic Co-operation and Development
13. SSA	Sub Saharan Africa
14. UN	United Nations
15 V1	variety 1
16. V2	variety 2
15. V3	variety 3
17 V4.	variety 4
18 WFP	World Food Programme

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## CHAPTER 1:

### INTRODUCTION

#### 1.1 Background to the problem

The Agriculture sector is a key livelihood for multitudes of small scale producers, (IMF, 2012). Maize (*Zea May L*) is one of the most important cereal crops grown worldwide following wheat and rice (FAO.,2012). Rice ,wheat and maize provides at least 30 percent of the food calories of more than 4.5 billion people in 94 developing countries (CGIAR Research program, 2018). In Sub Saharan Africa (SSA) and Latin America, maize is the most important food crop and is a key Asian crop (CGIAR R, 2018). Over 300 million people depend on maize for food, feed and as a source of income in SSA, (Rovere, 2010) . Forty to fifty percent of carbohydrates and proteins consumed in Malawi, Zambia and Zimbabwe, comes from maize (FAO, 2016). Maize is an important staple crop in SSA (FAO, 2016). More than 75 percent of cereal area in Kenya, Malawi, Zambia and Zimbabwe is constituted by maize (Jayne, et al, 2003). The average per capita consumption of maize as food is over 94kg/year in Kenya, over 100kg/year in Malawi, Zambia and Zimbabwe (Jayne, 2003). Maize is therefore a crucial part of the food security equation in SSA. . Fifteen percent (15%) of total GDP comes from the agriculture sector and the sector employs more than half of the total labour force (IMF, 2012)..

Fall armyworm(FAW) , Spordoptera , JE Smirth is native to tropical and subtropical regions of the Americas (FAO, 2018). It was first reported as present in Africa in January, 2016 (Goergen et al, 2016). Further research showed that the pest had spread to most of Sub-Saharan Africa (SSA), where it is causing extensive damage mainly to maize fields and to a lesser extend sorghum and other crops (.Prasanna et al, 2018). The pest was reported in Zimbabwe in September 2016 (U.N., 2018).

More than 80 species of plants can act as host to FAW which cause damage to economically important cultivated cereals such as maize, rice, sorghum and also to vegetables and cotton (FAO, 2018).

Fall armyworm has spread to over 30 countries in Africa, (Goergen et al, 2016). Evidence suggests that the type of FAW, introduced in Africa is the haplotype originating from South Florida (USA) and the Caribbean (.Prasanna et al, 2018). Mode of entry and dates of entry into Africa of FAW are not known (.Prasanna et al, 2018). Researchers are of the opinion that the caterpillar or its eggs may have reached the continent through imported produce (Briggs, 2017).

Fall armyworm has a number of unique characteristics which makes it a more devastating pest than many others Africa has experienced, (.Prasanna et al, 2018) .Fall armyworm's polyphagous behaviour, means the pest has many host plants and therefore difficult to control/eradicate (.Prasanna et al, 2018) . The pest has both the migratory habit and localized habit. In the migratory habit moth can fly over 500km in 24 hours (.Prasanna et al, 2018). Moth can travel large distances taking advantage of prevailing wind currents, e.g.,1600 km

from the Southern US of Mississippi to Southern Canada in 30hrs (.Prasanna et al, 2018). The use of wind currents for dispersal means the pest can quickly spread over large geographical areas causing extensive damage .The climatic conditions in most parts of Africa are conducive for the pest to be present throughout the year unlike in most areas of America where it appears seasonally due to cold winter months in which the pest dies. In some parts of Zimbabwe such as the Lowveld (agro ecological region 4 and 5) covering areas such as Chiredzi, Chibi, Muzarabani, the pest persist throughout the year. High temperatures enable many generations per season and there is always the preferred host plant (maize) in irrigation schemes throughout the year. Control of FAW is complicated by many factors such as the nocturnal behaviour of the adult moth, the boring activity of the damaging larval stage, the availability of a diverse alternative hosts plants and the resource poor nature of many farmers, (Kfir et al 2002). Furthermore FAW can easily adapt and resist many synthetic pesticides if not administered correctly (Prasanna et al, 2018).

The invasion of Africa by Fall armyworm is causing a serious threat to food security and adds to the insecurity caused by many other factors including extreme weather conditions such as the El nino induced drought in 2015/16 and the recent cyclone Idai which caused hundreds of deaths and left several families homeless and facing starvation in Mozambique, Malawi and Zimbabwe in March 2019. The 2015-16 El nino induced drought affected 40 million people and mostly small scale communal farmers who had not recovered when the Fall armyworm was discovered in 2016 (Prasanna et al, 2018) Its invasion of Africa also adds to the diversity of Lepidoptera pests of cereal crops which contributes to the increased negative impacts on production and food insecurity in the continent (Kfir et al, 2002).

Impacts of FAW on agricultural productivity in Africa are huge. Fall armyworm has the potential to cause yield losses of 8.3 million to 20.6 million metric tons per year in just 12 of Africa's maize producing countries in the absence of proper control methods (CABI, 2017). The level of these losses represents 21-53% of annual production of maize averaged over a three year period in these countries and their value is estimated at between USD2.48 billion and USD6.19 billion (CABI, September,2018) . The Centre For Agriculture and Biosciences International (CABI) predicts that FAW poses a major threat to food security and agriculture trade. FAW has since caused significant damage on over 280,000 hectares of maize in Malawi, Namibia, South Africa, Zambia and Zimbabwe, and can cause up to 70 percent crop loss, or total loss in some cases if unmanaged (FAO, 2018) . The level of damage witnessed is expected to create more than 200 million food-insecure people who depend on maize for food (FAO, 2018). Farmers can experience low revenue due to low yield and poor quality grain. Damaged grain is also prone to aflatoxins which can affect consumers..

Fall armyworm could have serious regional and international trade through strict scrutiny of produce from infected countries., (Joseph E Huesing B. P et al 2018). FAW can possibly migrate into Europe through countries such as Ethiopia and Asia (Joseph , et al., 2018).

Control measures for FAW should aim to take the form of integrated pest management (IPM) , (<http://www.push-pull.net>). Some of the sustainable options for the control of FAW are to replace highly susceptible varieties with identified resistant varieties, manipulating the timing of host plant development relative to pest presence, e.g. timing of planting which works by creating an asynchrony between the pest and critical growth stages.(Prasanna et al, 2018). These options are especially key in SSA in countries such as Zimbabwe, Zambia, Malawi and Mozambique where the majority of the farmers have limited access to safe and affordable FAW control options (Christian etal, 2018)

Climatic conditions in SSA vary greatly from region to region. The effects of FAW in Zimbabwe also vary from one agro ecological region to another and from, village to village in the same region depending on biotic and abiotic factors favouring the proliferation of FAW as well as the dominant livelihood activities of the community.

## **1.2 Problem Statement**

Fall armyworm is new to Africa and a lot is still to be learnt regarding effective and sustainable control measures (Joseph, et al., 2018) The loss in maize yield, a staple food crop in SSA due to FAW is increasing the food insecurity risk among vulnerable small scale farmers. Estimates have shown that potential loss due to FAW in 12 African maize producing countries is huge (Melanie, 2019). Between 4 million and 18 million metric tonnes out of a total expected production of 39 million tonnes could be lost. The economic cost could be between USD 1-4.6 billion per year (Meanie, 2019).

Control measures widely used in most of SSA is mostly the use of chemicals, (Prasanna, 2018) Chemical control measures have many challenges due to limited knowledge regarding their use and are detrimental to the farmers, the environment and to livestock (.Prasanna, et al, 2018). Most African small scale farmers are poor, a factor which also limits effectiveness of chemical control options due to lack of affordability. Fall armyworm has several characteristics which make it difficult to control or eradicate. The polyphagous behaviour of the pest means that the pest has many alternate host making cultural control measures such as crop rotation ineffective. In addition the boring activity of the larvae in maize and sorghum crops in which it enters the crop funnels and protects itself with excrement makes chemical control ineffective. The ability of the moth to fly long distances means the pest can quickly spread over wide geographical areas causing extensive damage {Prasanna, et al , 2018)

**1.3** The research was carried with the following objectives:

### **1.3.1 Main objective:**

To determine the effect of variety and planting time on FAW control in maize.

### **1.3.2 Specific objectives:**

1. To determine the effect of planting time on FAW maize damage
2. To determine the effect of maize variety on FAW damage and yield.

### **1.4 Research questions:**

The lack of effective and sustainable control methods for FAW which take into consideration the resource poor nature of farming communities in SSA is a challenge.

## **1.5 Hypothesis**

Planting time has no effect on FAW maize damage.

Maize variety has no effect on FAW damage

Planting time and maize variety has no effect on FAW damage

## **1.6 Justification:**

Loss in yield and trade due to FAW attack, compromises the livelihoods of many small holder farmers in SSA. Fall armyworm is a new pest and effective and sustainable control measures for this evasive pest are not yet there. The resource poor nature of many farmers in SSA requires the use of safe and sustainable control measures in the control of FAW. The unique characteristic of FAW requires integration of cultural control measures in an IPM strategy (K Fr et al, 2002). Identification and developing HPR combined with effective planting dates can be a key strategy as a site specific sustainable control measure in SSA where the majority of the farmers have limited access to safe and affordable FAW control options (Prasanna, et al, 2018) In Zimbabwe effective control of FAW should be site specific given that the climatic conditions which mainly influence the proliferation of the pest vary considerably from one agro ecological region to the other. Variation in climatic conditions is sometimes experienced within the same agro ecological region.

## **1.8 Outline of Thesis**

This thesis is comprised of 6 chapters of which chapter 1 contains the background to the study, objectives and the justification among other items. Chapter 2 is mainly literature review while chapter 3 details the materials and methodology of the study. Chapter 4 and 5 details results obtained and discussions. Chapter 6 summarises the study and has a conclusion and recommendations section.

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## **Chapter 2**

### **2.0 Literature Review**

#### **2.1 Introduction:**

FAW (*Spodoptera frugiperda*) is threatening the livelihoods of many small holder farmers through its destruction of maize, the staple food crop of many people in Africa. The pest is all over Sub Saharan Africa (SSA) causing extensive damage especially to maize fields and other crops (Goergen et al, 2016). Various estimates by different experts show that potential yield loss due to FAW in Africa's maize producing countries is huge. Losses of between 22 % and 67% in maize yield have been estimated in Ghana and Zambia valued in millions of United States dollar(USD) losses (Day, et al 2017). Loss of maize yield due to FAW has been estimated to 32% in Ethiopia and 47% in Kenya (Kumela et al, 2018). The maize production estimates for 2018 has been estimated at 65 million metric tonnes and between 20 -50% of this yield valued at USD 3.7 to 5 billion could have been lost due to FAW damage (Melanie, 2019). The control of FAW in Africa is complicated due to many factors. The ability of FAW to migrate quickly and breed quite fast, with an entire life cycle between 35 and 61 days has made efforts to eradicate the pest futile (FAO, 2018). Natural enemies for the pest are still very rare in Africa (FAO, 2018). No proven effective control measure for the pest has been identified (Briggs, 2017). African communities are poorly prepared to deal with fall army worm due to lack of resources and knowledge of the pest.

The immediate response to control FAW using pesticides in Africa has potential for posing danger to humans and the environmental due to exposure to pesticides residues on consumed produce or in the production environment (Joseph, 2018).

Pesticides exposure poses more danger to women and children as they primarily manage agriculture operations in Africa (CABI, 2018) Use of pesticides could result in inevitable damage to populations of natural enemies and predators of FAW and other major pests , (Joseph, et al., 2018). Furthermore unguided use of pesticides as is currently the case in SSA could result in FAW developing resistance thereby complicating efforts to control it.

The life cycle of Fall armyworm in tropical climates is between 30-40 days and avoiding treating successive generations with the same insecticide or pesticides with similar mode of action is critical (.Prasanna et al, 2018)

#### **2.2 Importance of Maize to Smallholder farmers in Developing Countries**

Maize is the most important staple crop in SSA (OECD, FAO, 2016. Maize , wheat and rice provides at least 30 percent of the food calories of more than 45 billion people in 94 developing counties, (CGIAR Research program, 2018).

Maize is staple food in developing countries providing food for 900 million people earning less than US\$2 per day (CGIAR, 2018) Maize plays a key role in the food security equation in Sub Saharan Africa.

### **2.2.1 An overview of Food insecurity in SSA**

Food insecurity in SSA has been a long standing problem. The percentage of undernourishment is the highest among developing regions (FAO, IFAD and WFP, 2015). Slow progress towards food security has been attributed to low productivity of agricultural resources, high population growth rates, political instability and civil strife, (OECD-FAO, 2016). The Agriculture sector contributes 15 percent of total GDP (OECD, FAO, 2016).

Over 50% of the labour force is employed in the agriculture sector and mostly from within the rural population providing livelihoods for multitudes of small scale producers, (IMF, 2012) . About 80 percent of all farms in SSA are constituted by small scale farmers and employ nearly 175 million people directly (AGRA, 2014). Half of the labour force is constituted by women in many of the countries (FAO, IFAD AND WFP, 2015)

### **2.2.2 The invasion of Africa by fall armyworm**

The arrival of fall armyworm in the African continent is compounding the already existing problems. The effect of climate change being felt unevenly across Asia, SSA and Latin America is already producing catastrophic loss in yields due to heat stress , disease and pest thereby worsening the food insecurity situation in developing countries (CGIAR, 2018) The ability for rapid spread and causing wide spread damage to crops of FAW makes it a serious threat to the food and nutrition security and livelihoods of hundreds of millions of farming households in SSA (Prasanna, 2018). The 2016/17 FAW outbreak arrived when households were still suffering from the effects of the 2015/16 El Nino –induced drought which affected an estimated 40 million people (Prasanna, et al, 2018).

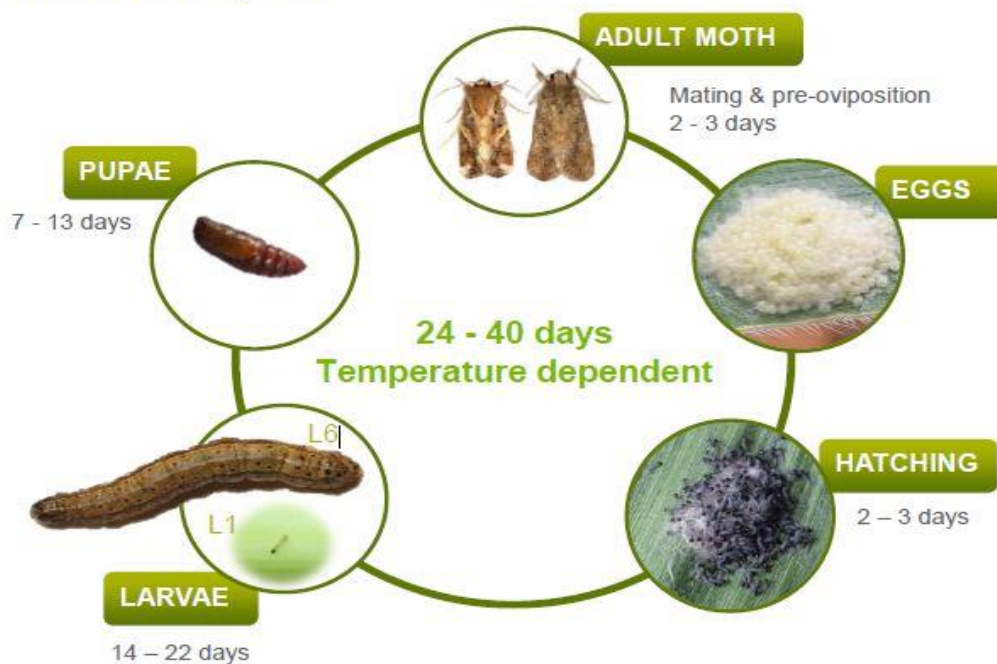
Yield losses of 8, 3 to 20, 6 M metric tons per year with a value of USD2.48 and \$6.19 billion in 12 of Africa’s maize producing countries can potentially be caused (CABI, 2017).

The Fall armyworm outbreak in Africa is also impacting on several seed companies resulting in potential seed shortages, (Joseph et al, 2018) There is also possible impacts on regional and international trade as unconfirmed reports of phytosanitary measures have been reported in some borders (Joseph, et al., 2018) Strategies for monitoring and controlling of FAW are presently limited since the pest is new to Africa (Prasanna,et al 2018). Pest suppression efforts have been primarily focusing on application of synthetic pesticides many of which have high potential to damage, humans, animals and the environment (Prasanna,et al, 2018). Furthermore these pesticides are expensive and vulnerable community members are limited on choice and often opt for the cheapest available pesticides. In most cases broad spectrum

pesticides are often used with potential to harm beneficial insects as well as the applicator, livestock and the environment.

The danger in the unguided use of insecticides is promoting the selection of resistant insects, (Lima et al, 2006). Control of FAW is also complicated by the fact that many farmers lack scouting and early identification techniques. Farmers often discover the pest in their fields when extensive damage has already been done. Recognition of the pest is therefore important.

## FAW Life cycle



**Source: Syngenta 2018**

### 2.2.4 Description of life cycle:

The Life cycle of FAW varies from 30 days to 90 days depending on prevailing temperatures. The pest completes its life cycle in 30 days when temperatures are around 28 degrees during warm summers. Life cycle may extend to 60-90 days when temperatures are cool. FAW does not have the ability to diapause (biological resting period) and as a result infestations may occur throughout the year where the pest is endemic. The pest arrives seasonally in non endemic areas and comes when conditions become favourable during warm summers. Only

one generation may be obtained before pest becomes locally extinct in non endemic areas. FAW is endemic in natural region 4 and 5 of Zimbabwe) and only arrives by migration to the cooler highland areas such as Agro ecological region 1 and 2. FAW eggs are deposited in layers, but most eggs are spread over a single layer attached to foliage. The number of eggs per moth varies considerably. Total egg production per female is greater than 2000. Eggs may be covered or not covered. Eggs hatch in 2 to 3 days during warm summer.

#### **2.2.6. Larval Stage**

FAW has six larval instars. Young larvae are greenish with a black head. The colour of FAW larva turns to a more orange colour in the second instars. Head capsule widths range from about 0.3 mm (instar 1) to 2.6 mm (instar 6), and larvae attain lengths of about 1 mm (instar 1) to 45 mm (instar 6) In the second instar, but particularly the third instar, the dorsal surface of the body becomes brownish, and lateral white lines begin to form. In the fourth to sixth instars the head is reddish brown, mottled with white, and the brownish body bears white sub dorsal and lateral lines. Elevated spots occur dorsally on the body; they are usually dark in colour and bear spines. The face of the mature larva may also be marked with a white inverted “Y” and the epidermis of the larva is rough or granular in texture when examined closely. In addition to the typical brownish form of the FAW larva, the larva may be mostly green dorsally. In the green form, the dorsal elevated spots are pale rather than dark. The best identifying feature of the FAW is a set of four large spots that form a square on the upper surface of the last segment of its body (Figure 2). Larvae tend to conceal themselves during the brightest time of the day. Duration of the larval stage tends to be about 14 days during the warm summer months and 30 days during cooler weather. Mean development time was determined to be 3.3, 1.7, 1.5, 1.5, 2.0, and 3.7 days for instars 1 to 6, respectively, when larvae were reared at 25°C (Pitre and Hogg 1983).

## **FAW LARVA**



Plate 1 larva

### **Damage caused:**

The 1<sup>st</sup> instar makes small windows on leaf surface of the maize crop. Infestations often go unnoticed. Larvae feed for 2 to 3 weeks. Full grown larva is 2, 5-3.8 cm. It produces trash or excrement which forms dry dust. Larvae of FAW have great appetite and consume 80% of total food intake in the last few days. Larvae damages both vegetative and reproductive parts of the maize plant.

### **2.2.7. Pupal Stage**

The FAW normally pupates in the soil at a depth 2 to 8 cm. Pupation can also occur in Stover of maize plants. The larva constructs a loose cocoon by tying together particles of soil with silk. The cocoon is oval in shape and 20 to 30 mm in length. If the soil is too hard, larvae may web together leaf debris and other material to form a cocoon on the soil surface. Pupation can also occur in leaf sheath, stems or ears. The pupa is reddish brown in colour, measuring 14 to 18 mm in length and about 4.5 mm in width. Pupa stage duration is about 8 to 9 days during the summer, but reaches 20 to 30 days during cooler weather. The pupa stage of FAW cannot withstand protracted periods of cold weather. For example, Pitre and Hogg (1983) studied winter survival of the pupa stage in Florida, and found 51% survival in southern Florida, but only 27.5% survival in central Florida and 11.6% survival in northern Florida. This range is approximately between 25.1°N to 30.3°N latitude and represents a January (winter) temperature range of 18-24°C (Capinera, 1999).

2.2.8. Adult Stage Moths of adult FAW have a wingspan of 32 to 40mm. Forewing of male moth is shaded gray and brown with triangular white spots at the tip and near the centre of the wing. Forewings of females are less distinctly marked, ranging from a uniform greyish brown to a fine mottling of gray and brown, (Ashley et al 1989). Both sexes have a hind wing which is iridescent silver-white with a narrow dark border. Adults are nocturnal, and are most active during warm, humid evenings. After a preoviposition period of 3 to 4 days, the female moth normally deposits most of her eggs during the first 4 to 5 days of life, but some oviposition

occurs for up to 3 weeks. Duration of adult life is estimated to average about 10 days, with a range of about 7-21 days.

Hosts plants:

FAW is highly polyphagous and feeds on over 80 crops. Larvae prefer maize/corn and sweet corn. Plant parts attacked include seedlings to grain ready for harvest. Can cut stems below surface like cutworm or cause dead hearts in plants.

### **2.3 Conceptual /Theoretical framework**

Fall armyworm will continue to be a significant pest for a longer period in Africa and it is therefore necessary to develop effective and sustainable control methods. Such approaches must take into consideration the resource poor nature of small holder farmers, (B.M .Prasanna et al, 2018) African countries should turn to lower risk solutions to fight FAW, (Melanie, 2019). The use of resistant varieties and timing of planting is part of a sustainable integrated pest management (IPM) strategy which can be used to mitigate damage caused by FAW in small holder farming set ups. The use of host plant resistance (HPR) has been studied in recent years and has the potential for use as a strategy to control FAW in maize crops. Host Plant Resistance is compatible with other control methods and often exhibits synergistic effects with insecticides and natural enemies, ( A Zevedo et al, 2002; Janini et al , 2011; Jesus et al 2014) Plant defence mechanisms include escape in space and time , incompatible biological associations, physically and chemically, derived barriers and accommodation by replacement or repair of damaged parts, (Teethes, 2017). Genetic resistance to insects' pests plays a key role in the attempt to enhance ecological stability in agricultural crops, (Teethes, 2017). The resistance mechanism in maize occurs through antibiosis when the negative effects of a resistant plant affect the biology of the insect pest utilising the plant as a host (Smith, 2005) the effects of an antibiotic plant may range from mild to lethal and are the result of either chemical or morphological plant defences. Antixenosis is characterised by the presence of morphological or chemical plant factors that adversely alter insect behaviour and as a result the insect can search for an alternate host plant. The plant responds to pest damage

Time of planting is an important factor to consider when controlling pests. The choice of planting date is usually dictated by many factors such as weather, markets, labour availability (Phillips, 2005). Farmers should however consider a planting date to grow the crop outside the pest window. For many pest and crop systems, planting date determines pest status. If a pest emerges and finds very few preferred host crops available in summer for example, the majority of the pest population may be attracted to the available host and will cause damage to such crop. If however there are many crop and non crop host plants available in early summer, then the pests will be more likely to disperse more widely and chances of damage occurring on any one crop will be reduced (Phillips, 2005).

Pest such as thrips infest early planted crops in high numbers but are usually not a problem on later planted crops (Phillips,2005). For certain insects, establishing a crop early and getting ahead of the problem (crop gets to a less or non –susceptible physiological stage) can be a practical solution to management. Earworms on sweet corn are less of a problem in early

planted crops (Phillips, 2005). Depending on whether the pest is endemic in the area or not, farmers can experiment with different planting dates and then adjust planting schedules accordingly to avoid peak pest pressure.

Plant resistance to insect damage is one of several cultural control methods (Teeths, 2017). Insect resistant cultivars combine the effects of natural, biological, and cultural insect suppression tactics and is ecologically, and environmentally advantageous (Teeths, 2017).

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## **Chapter 3**

### **3.1 Materials and methods**

#### **3.2 Introduction:**

The control of fall armyworm requires a site specific approach given the fact that many of the conditions in Zimbabwe and SSA vary from region to region and sometimes within regions. Some regions such as the eastern highlands of Zimbabwe(Nyanga area), and Mashonaland East (Marondera area) have very cold winters while others such as the Lowveld areas of Zimbabwe (Muzarabani, Chiredzi etc) have warm temperatures throughout the whole year.. The variation in weather conditions as well as the dominant livelihood practices has a great influence in the survival and proliferation of FAW. Peter and Hogg 1993 studied the survival of FAW pupae in Florida and found 51% survival in Southern Florida but only 27, 5 % survival and 11.6 % survival in Central and Northern Florida respectively. Such variation influences the population dynamic of the FAW and the severity of damage caused from region to region. In its country of origin, the FAW appears seasonally, (Prasanna et al , 2018) The initial response to fall armyworm control by many African governments was through the use of chemical insecticides,(Prasanna, et al, 2018). Chemical control is detrimental to the environment, livestock and to the farmers (Joseph et al, 2018). The repeated use of non selective, insecticide with similar active ingredient or same mode of action is likely to result in resistance development by the FAW as well as proliferation of resistant pests (Prasanna et al, 2018). The development of safe and sustainable control methods tailor made for smallholder farmers is therefore mandatory.

This paper seeks to explore the effect of 4 commercial maize varieties and date of planting on FAW attack. The 4 maize varieties are among the commonly grown in Zimbabwe. The 3 dates of planting represent common planting periods among smallholder farmers in Zimbabwe mainly as a result of mainly differences in socio economic factors.

#### **3.2 Study site description**

The trial was conducted in Kandava village under Seke District in ward 4 in Mashonaland East Province under Zimbabwe's agrological region 2. The site Homestead is located 18.1279 degrees South and 31.2701 degrees east. Site is 8 km from Marondera /Hwedza Junction along Chitungwiza to Marondera road. Height above sea level is 1600 metres total annual rainfall ranges from 600 to 800mm. Most of the rainfall is received from late October to April.

There is usually very little to no rainfall during winter months (May to July) and mid season dry spells are experienced in January and of late February. Mean annual temperatures range from 12 degrees to 32 degrees during winter and summer respectively. Soils are predominately poor sandy with extremely low pH and little inherent organic matter. Mean annual temperatures during summer range from 24 degrees Celsius to 32 degrees and 8 to 24 degrees during winter.

### 3.2.1 Management:

#### **3.2.1 Management of study site:**

Land preparation was done using an ox drawn plough to emulate the practise by the majority of villagers and soil samples were taken soon after land preparation for analysis. The maize varieties were planted in plots measuring 4m x 5m. Plant spacing was 0,75m X 0,25m. Two seeds were planted per station and immediately thinned to one after germination to leave a plant population of 53 333 plants per hectare.

Compound D Fertilizer(7N :14P :7K) was side dropped in planting stations at the rate of 350kgs per hectare and top dressing was split applied at 150kgs per ha at 4 weeks and 6 weeks giving a total of 300kgs per hectare ammonium Nitrate (34,5% N ). The trial was under drip irrigation to safe guard against total crop failure due to drought. Irrigation was applied as a supplementary measure. Weeding was done 3 times using a hand hoe and the site was kept weed free at most times.

### 3.2.2 Irrigation:

Although the trial was under rain fed conditions, two survival irrigations were applied on, 11, January and 15 February 2019. A total of 20mm was applied on each occasion using drip irrigation system.

### 3.3 Maize hybrids and Experimental design:

Four mid seasons maize hybrids were selected for evaluation in a completely randomised block design. Selected hybrids are among the most commonly grown by villagers and these were SC649, SC637, and Sc633 (all from Seed CO and DKC8053 from Tocek Investments. The four maize hybrids were planted over three planting dates of 15 November, 15 December and 28 December signifying early, midseason and late planting respectively. FAW infestation was natural and the site was previously grown to maize resembling the monoculture practises by the community which also ensured that sufficient infestation to the treatments will occur.

The trial was held under no chemical spray conditions for all treatments. The experimental design was a 4X3 factorial which was laid down in completely randomised blocks giving 12 treatments replicated 3 times to give a total of 36 treatments. Blocking was done to reduce the effect of environmental factors such as soil texture and slope. Plot sizes were 4x5 metres and distance between plots was 1 metre while that between blocks was 3 metres. The trial was under supplementary drip irrigation.

Table 1

Block 1	Block 2	Block 3
V4D3	V3D2	V1D1
V1D2	V4D3	V1D3
V2D1	V4D2	V2d2
V3D1	V2D2	V3d2
V1D1	V2D1	V2d3
V2D3	V1D3	V3d1
V4D2	V4D1	V4d2
V3D3	V3D1	V3v3
V1D3	V3D3	V4d1
V2D2	V1D1	V4d3
V4D1	V2D3	V1d2
V3D2	V1D2	V2d1

### 3.3.1 EXPERIMENTAL DESIGN AND PLOT LAYOUT

#### Key

D1-Planting date- 15 Nov 2018

D2-Planting date- 15 December 2018

D3- Planting date 28 December 2018

V1- DKC8053, V2-Sc649, V3-Sc633, V4- Sc637

#### 3.4 Data collection

##### 3.4.1 Sampling & Data Analysis

A plant was randomly selected to be the 1<sup>st</sup> of 5 consecutive plants in each treatment as from the 2<sup>nd</sup> week after germination for leaf score measurements. The first row was omitted for edge effect and sampling was done as from the second row of each plot. The first metre on the sampling row was also omitted for edge effect. Each of the 5 consecutive plants was examined to determine number of damaged leaves and leaf lesion size. Records of foliar damage ratings on a 9 point visual rating scale (1 – no damage to 9 –severe foliar damage), (Davis William, 1992), (Maturiki et al, 2018). A score was given for each plant and an average was recorded for the treatment. Measurements were taken for V5, V8, VT and R5 growth stages.

The number of affected plants was also recorded at each sampling for particular growth stages and on the same plants sampled for leaf damage score. Observations (scouting) started at v2 growth stage but measurements started at v5 growth stage. Exit holes and kernel score as well as yield measurements were done at R5 stage (maturity). Whole plot counts were done to determine the number of plants affected by FAW out of the total at R5 growth stage. The number affected for each treatment was expressed as a percentage of the total. A total of 100 plants were sampled per each treatment to determine exit holes at R5 stage. Fifty plants

were sampled per treatment to determine kernel score at R5 stage and net plots were harvested and the cobs were sun dried to 12 % moisture to determine yield.

Yield figures were adjusted to per hectare basis. Discard as a result of FAW damage and subsequent secondary infection of grain was also recorded following harvesting.

Data collected were leaf damage score as explained above, exit holes, kernel score (modified Davies scale), Yield (t/ha), and % Discard yield (t/ha) as a result of FAW damage.

Other recordings were rainfall and average minimum and maximum temperatures for the season.

### 3.5 Data analysis:

Data collected was cleaned and subjected to analysis of variance (ANOVA) using Genstat 16.1 release. Significant difference ( $P < 0.05$ ) among treatments were separated using fisher's least significant difference (LSD).

### 3.7 Ethical considerations:

The no spray trial was held in the village thereby posing great risk for the proliferation of the deadly FAW pest to the rest of the community.

Mitigatory measures were that the trial was sited at an isolated homestead. Cultural control measures were taken soon after end of data collection aiming at destroying pupae in maize above ground biomass.

### 3.8 Summary

A 3X4 factorial experiment was carried out in completely randomised block design with a total of 36 treatments to determine the effect of maize variety and planting date on FAW attack. Data collected were leaf average scores recorded from V5 to R5 growth stages. Data recorded were number of plants affected, leaf damage score. Additional data collected were for average exit holes (aeh), kernel average scores (kas), yield (t/ha) and discard as a result of secondary infection of grain by parasitic fungi after FAW damage. Data was subjected to Annova analysis.

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## CHAPTER 4: RESULTS

Effect of Maize Variety and Time of planting on Leaf Damage and number of plants affected by FAW:

### 4.1.1 Abstract:

The control of FAW in Africa is still a challenge 3 years after its invasion of the continent in 2016. Time of planting and maize variety is a cultural techniques that can be used to sustainably control pests by smallholder farmers in Zimbabwe. The objective of this study was to evaluate the effect of maize variety and time of planting on FAW attack. Four maize varieties were planted over three planting dates and were evaluated for resistance to damage by FAW using foliar damage score (Davis scale). The number of plants affected by FAW out of the sampled plants for each treatment was also recorded. Whole plots were analysed for number of plants affected by FAW at R5 maize growth stage. The maize growth stages evaluated were V5, V8, VT and R5. The commercial hybrids evaluated were DKC8053, SC649, SC633 and SC637. Planting dates were early planting (15 November), midseason planting (15 December) and late planting (28 December). The 4x3 factorial experiments in complete randomised blocks with 3 replications were subjected to ANOVAs analysis using Gernstart version 14. Blocking was done to reduce the effect of environmental factors such as slope and soil type.

Results obtained for v5 and v8 showed lower levels of FAW infection. The trend shifted at later stages (VT and R5) as FAW preferred late crops than early crop. Variety had no significant effect on average leaf damage score and number of plants affected for all measurements observed at  $p < 0.05$ . Time of planting was significant for observed treatments at  $p < 0.05$  for stages VT and R5. Early planting had the least damage with a score of 1.5 at R5 growth stage while late planting had the highest score of 4.50. Time of planting was significant on number of plants affected at  $p < 0.05$  while variety was not. At R5 maize growth stage, early planting had the least number of plants affected by FAW (21%) while late planting had the highest number of plants affected (83%). Fall armyworm attack in the late crop was very high and the rate of infection was increasing at an increasing rate from V8 to R5 stages.

**Key words:**

Average leaf score (ALS)

maize variety,

time of planting

#### **4.1.2 Introduction:**

Plant defence mechanisms include escape in space and time, incompatible biological associations, physically and chemically derived barriers and accommodation by replacement or repair of damaged plant parts, (Teeths,2017). Genetic resistance to insect pests is key in enhancing ecological stability in agricultural crops. According to Teeths,2017, plant resistance is defined as the consequence of heritable plant qualities that result in a plant being relatively less damaged than a plant without the qualities. Plant resistance to insects is an important cultural control method. Teeth, 2017 defined cultural control methods as agronomic practices which reduce insect pest abundance and damage below that which would have occurred if the practice had not been used. Insect –resistant crop varieties suppress insect pest abundance or elevate the damage tolerance level of the plants. Teeths,2017). There are three different types of resistance namely antibiosis, antixenosis and tolerance (Teeths, 2017). Antibiosis affects the biology of the insect while antixenosis affects its behaviour (Teeths,2017). Tolerance is a plant respond to an insect pest. Antibiosis and antixenosis resistance cause an insect response when the insect attempts to use the resistant plant for food, oviposition or shelter (Teeths, 2017).. Use of insect resistant crop varieties is economically, ecologically, and environmentally advantageous (Teeths, 2017).

Maize resistance to FAW and to other lepidopteran pests varies depending on genetics. . (Davies & Williams , 1993) rates the extend of leaf damage or ear damage relative to susceptible control on a scale of 1 to 9. Research efforts are currently being devoted to identifying and developing corn germplasm that confers resistance to multiple insect pests at various growth stages (Wilson et al, 1995).

Some corn germplasm resistant to *S frugiperda* has been developed at Mississippi State for the Southern States (Brooks et al 2007, Wiseman et al 1996)

Time of planting is dictated by many factors such as markets, weather, labour availability among many others. Growers should consider a planting date to grow the crop outside the pest window for important pests. The timing of crop development can have a great effect on its susceptibility to insect pests. Planting date can determine pest status of a pest for most crops (Phillips, 2005) .Thrips as an example infest early planted crops in high numbers but are rarely a problem in later planted crops.. Corn earworms on sweet corn are rarely a problem in early planted crops (Phillips, 2005).

#### **4.1.3 Materials and methods (see 3.1)**

Four maize varieties were analysed for foliar damage by FAW. The varieties were planted over three planting dates in randomised blocks replicated 3 times. Planting was split over 3 dates of 15 Nov, 15 December and 28 December, signifying early, mid, and late planting. (See chapter 3 section 3.1 for a detailed materials and methods)

#### **4.1.4 Sampling procedure:**

Sampling procedure is the same as outlined in 3.4.1

#### **4.1.5 Challenges encountered during data collection:**

Data collection was skipped when it was due during rainy weather periods. Data collection date was moved 2 days during the R5 stage. Although measurements were targeted to start from v2 stage, the crop was not infested when data was due for collection.

#### **4.1.6 Results:**

##### **4.1.7 V5 growth stage:**

##### **4.1.8 Effect of variety on FAW damage**

Variety had no significant effect on average leaf damage score for all treatments observed at  $p < 0.05$ . SC649 and SC633 had the least score of 1.04. SC637 had the highest score of 1.31

##### **4.1.9 Effect of planting time on leaf damage by FAW at V5 maize growth stage:**

Time had no significant effect on observed treatments at  $p < 0.05$  for v5 growth stage. Early planting had the highest score of 1.5 while late planting had the least score of 0.88.

#### **4.2 Time variety interaction:**

The interaction of planting time and maize variety had no significant effect on observed treatments at  $p < 0.05$ .

##### **4.2.1 Effect of variety on number of plants affected at V5 maize growth stage**

Variety had no significant effect on number of plants affected for all treatments observed at  $p < 0.05$ .

#### 4...2.2 Effect of Time of Planting on number of plants affected:

Time of planting was not significant on all observed treatments at  $p < 0.05$

4.2.3 Table 2

Treatment	LAS (leaf average score)	Number of plants affected
V1 (DKC8053)	1.13n/s	0.78n/s
V2 (SC649)	1.04n/s	0.44n/s
V3 (SC633)	1.04n/s	0.56n/s
V4 (Sc637)	1.31n/s	0.89
E (Early planting)	1.5n/s	1n/s
M ( mid season planting)	1.02 n/s	0.75n/s
L (Late planting)	0.88n/s	0.25n/s
Grand mean	1.13	<b>0.67</b>
LSD	0.066	1.075
LSD (time)	0.572	1.075
CV%	6.4	54.5
Se	<b>0.059</b>	0.066
P value	0.05	0.05

Table 2: Summary results for v5 growth stage showing means for leaf scores and number of plants affected for variety and time of planting

#### 4.2.4. V8 growth stage:

#### 4.2.5 Effect of maize variety and number of plants affected by FAW

Maize variety had a significant effect on observed treatments at  $p < 0.05$ . v1 and v2 were ranked the same with means of 1.156 and 1.2. V3 and V4 were also ranked the same with means of 1.644 and 1.622

#### 4.2.6 Effect of Time of planting:

Time of planting was significant on observed treatments at  $p < 0.05$ . Mid season planting had the highest score of 1.717 while early planting and late planting were ranked the same with average scores of 1.3 and 1.2 respectively. fig 2 below shows the distribution of means as a result of time of planting.

#### 4.2.7 Effect of maize variety on number of plants affected:

Maize variety had a no significant effect on observed treatments at  $p > 0.05$

#### 4.2.8 Effect of Time of Planting on number of plants affected:

Time of planting was not significant on all observed treatments at  $p > 0.05$

4.2.9 Table 3 below shows summary results for v8 growth stage showing means for leaf scores and number of plants affected for variety and time of planting

Treatment	LAS (leaf average score)	Number of plants affected
V1 (DKC8053)	1.156a	0.78n/s
V2 (SC649)	1.2a	0.78n/s
V3 (SC633)	1.64a	1.78n/s
V4 (Sc637)	1.633bc	2n/s
E (Early planting)	1.3a	1.33n/s
M ( mid season planting)	1.717	1.75n/s
L (Late planting)	1.2	0.92n/s
Grand mean	<b>1.406</b>	<b>1.33</b>
LSD(variety)	0.4324	1.274
LSD (time)	0.3745	1.103
CV%	9.1	12.5
Se	<b>0.3458</b>	0.167
P value	0.05	0.05

Table 3 summary of results for v8 growth stage

### 4.3 VT Growth stage

#### 4.3.1. Effect of Maize variety on FAW attack at VT growth stage:

Variety had no significant effect at VT stage on all observed treatments at  $p < 0.05$

#### 4.3.2 Effect of Time of Planting:

Time of planting had a significant effect at  $p < 0.05$ . Late planting had the highest score of 3.3 while early planting and mid season planting were the same with means of 2.57 and 2.53 respectively. Fig 3 below shows effect of time at VT growth stage.

#### 4.3.3 Effect of variety on number of plants affected

Variety had no significant effect on number of plants affected for all treatments observed at  $p < 0.05$ .

#### 4.3.4 Effect of Time of Planting on number of plants affected:

Time of planting was significant on all observed treatments at  $p < 0.05$  Early planting and mid season planting had the least number of plants affected. Late planting had the highest number of plants affected with 4.67 plants.

**4.3.5 Table 4 below shows summary results for VT growth stage showing means for leaf scores and number of plants affected for variety and time of planting.**

Treatment	LAS (leaf average score)	Number of plants affected
V1 (DKC8053)	2.84 n/s	4.33n/s
V2 (SC649)	3.09n/s	4.11n/s
V3 (SC633)	2.64n/s	3.89n/s
V4 (Sc637	2/62 n/s	4.33n/s
E (Early planting)	2.57n/s	3.92a
M ( mid season planting)	2.53 n/s	3.92a
L (Late planting)	3.3 n/s	4.67b
Grand mean	<b>1.406</b>	<b>3.58</b>
LSD(variety)	0.369	0.619
LSD (time)	0.640	0.536
CV%	6.8	12.5
Se	<b>0.1039</b>	0.495
P value	0.05	0.05

Table 4 Results for VT growth stage

**4.3.6 R5 growth stage:**

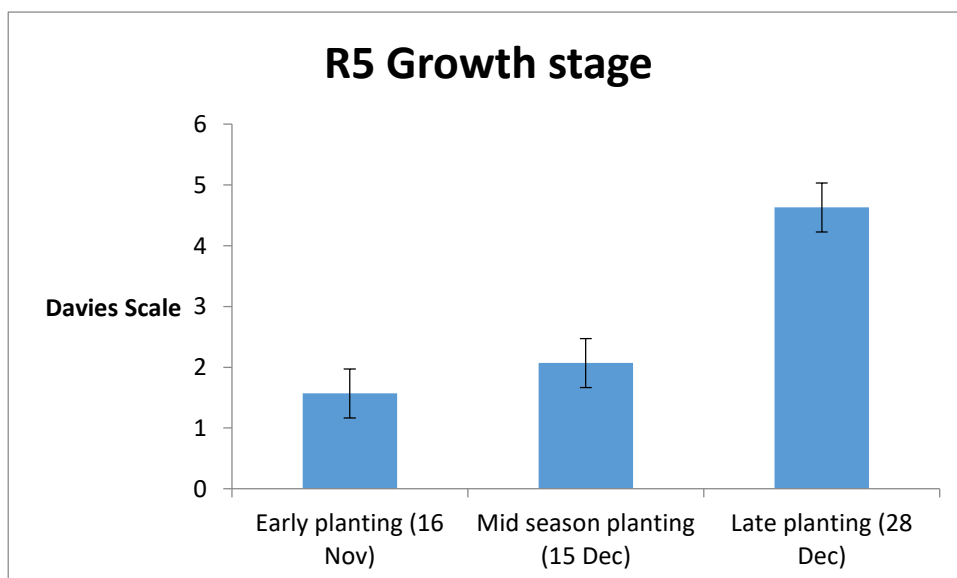
**4.3.7. Effect of maize variety on FAW attack at R5 growth stage:**

Variety had no effect on observed treatments at  $p < 0.05$

**4.3.8 Time of Planting:**

Time of planting was significant for observed treatments at  $p < 0.05$ . Early planting had the least score of 1.57 while late planting had the highest score of 4.63. Early planting and mid season planting were ranked the same with means of 1.57 and 2.07 respectively.

**Fig 4 below shows the effect of time of planting for Early planting (E), mid season (M) and Late planting at R5 stage.**



**Fig 4 Effect of time of planting on leaf damage (Davies scale)**

**4.3.9 Effect of maize variety on number of plants affected (whole plot counts):**

Maize variety had a no significant effect on observed treatments at  $p < 0.05$

**4.4. Effect of time of planting on number of plants affected (whole plot counts at R5 only):**

Time had significant effect  $p < 0.05$  on observed treatments . Early planting had the lowest number of plants affected with a mean of 21 percent. Late planting had the highest number of plants affected with a mean of 83.42%.

**Figure 4.1** below shows percent plants affected for early, mid and late planting basing on whole plot counts at R5 stage.

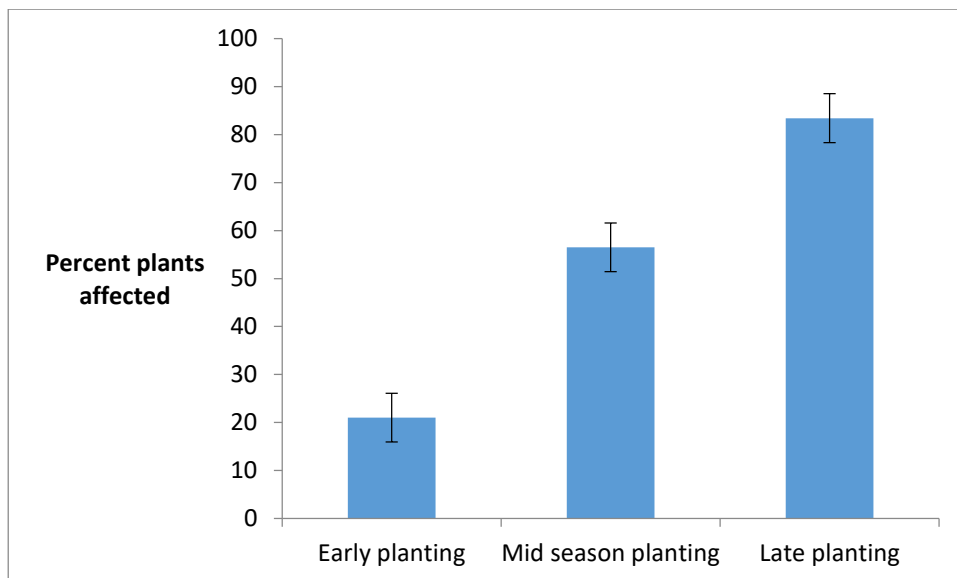
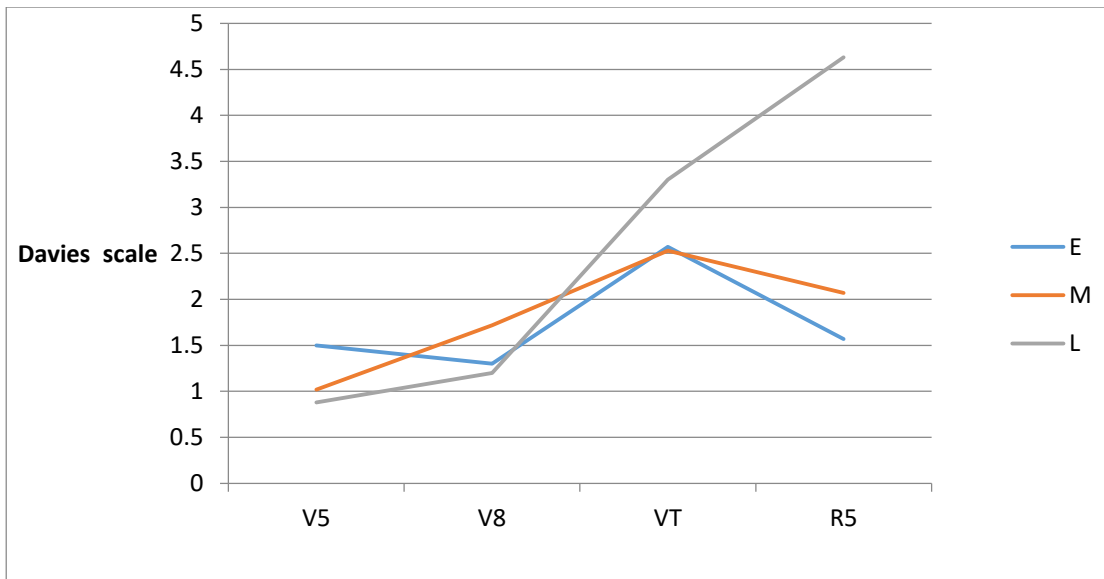


Fig 4.1: Percent number of plants affected by FAW at R5 stage:

Fig 4.2 below shows the trend in FAW infestation for four growth stages (V5, V8, VT and R5) for early planting (E) mid season (M) and late planting (L).

**4.2 FAW INFESTATION AT DIFFERENT GROWTH STAGES**

Fig 4.2 below shows FAW infestation on different maize growth stages



**Fig 4.2. Trend analysis of FAW attack at different growth stages**

Plates 1 and 3 below shows damage by FAW on late planted crops compared to early planted crop (right)



Plate1 (late crop)



Plate 2 (early crop)

#### **4.4.3 Discussion:**

.At v5 stage there was little or no FAW infestation for late planted crop and mid season planted crop. Relatively high infestation was observed for early planted crop compared to late and mid season crops. This trend could be possibly due to time of infestation which was only at its initial stages for late planted crop compared to early and late planted crops. FAW attack at V8 started to shift showing preference for mid and late planted crops. Rate of infestation for late crop is increasing at an increasing rate while that of early planted crop is increasing at a decreasing rate. This trend is probably due to the fact that the late crop which has soft and tender leaves is easier to feed on than the lignified had leaves of the early crop. The rate of

increase in attack continued to show the same trend at VT maize growth stage (refer to fig 4.2) at this stage the trend clearly shows preference for the late planted crop compared to early crop. At R5 maize growth stage, Leaf score for late crop reached 4.5 compared to 1.5 and 2 for early and mid season crops. FAW is clearly showing preference for late planted crops as shown by the graph in fig 4.4.2. The vulnerability of late crops is further verified by the number of plants affected as shown in fig .4.1 Late planting i.e. 28 December resulted in 83.42 % of plants affected by FAW compared to 21% for early planting (15 November) and 56.5 % for mid season planting (15 December). Results obtained showed that early planting had the least damage and least number of plants affected. Both leaf scores and number of plants affected increased in the late planted crop for later stages (refer to fig .4.2.). This trend showed preference for soft tender leaves of the late planted crops.

The results are in line with the findings of David, 2018 who recommended early planting to avoid peak migration of the FAW adult moth. David, 2018 also asserted that farmers should avoid staggered planting of maize as the older crop cause build up of the pest that can ravage the younger crop that is planted later. Late planting showed the highest number of plants affected at R5 stage with a grand mean of 3.58. Leaf score was also highest in late crops with the highest score of 4.63 at R5 stage. Results obtained are in line with the findings of Gebre, et al 1989, which showed that evidence from research with other stem borers showed that early planting has higher chances of escaping pest infestation compared to delayed planting. This is also in line with the recommendations of CABI ([www.plantwise.org](http://www.plantwise.org)) who recommended early planting to escape FAW attack. Mitchell, 1978 also noted that early planting is the most important cultural practice employed widely in Sothern States and early maturing varieties to mitigate against FAW.

Time of planting has several other advantages apart from avoiding peak pest periods. Early planting enables plants to optimise heat units resulting in fast growth rate and ultimately high yield being obtained.

Results obtained however still need to be confirmed by yield as the overall determining factor. This is so because plants may recover from pest damage and still attain high yield despite severe foliar damage.

The 4 maize varieties had no significant effect with regards to FAW attack for three of the four maize growth stages observed (R5, VT and R5) except for v8 stage.

Results obtained showed that the level of resistance shown by the varieties was not significant to warrant complete protection. This is in line with the observations of Mc Million et al, 2017 who observed that there are few sweet corn varieties which offer resistance to earworms and FAW. Capinera, 2017 also noted that partial resistance is present in some corn varieties but is inadequate for complete protection. Georgen et al, 2016 also observed that there are presently no African adapted varieties showing FAW resistance. Varieties used could probably have been derived from the same parents and shows the same effect when subjected to pest pressure. Breeders could possibly be using the same pool for developing their varieties and hence similarity in performance. This is particularly so given that three of the varieties used were from the same company.

#### **4.9.1. Recommendations**

Farmers should always plant early to avoid excessive crop damage by fall armyworm in agro ecological regions similar to Mashonaland East of Zimbabwe where FAW is not endemic. Late planting should be avoided where possible as the greatest foliar damage and the highest number of plants affected occurs on late planted crops. Screening of varieties for FAW resistance should be continued and should evaluate germplasm from a wider range.

#### **4.9.2 Conclusion**

The four maize varieties did not offer significant difference in terms of leaf damage as well as number of plants affected. Time of planting was significant on all measured parameters of leaf average score and number of plants affected. Early planting is therefore recommended in areas where FAW has a migratory habit.

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Sorghum /Legume Intercrop on Stem Borer Damage and Yield of Sorghum in the South Eastern Dry Areas Of Zimbabwe2017*Gallery Proof*9

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## **Chapter 5:**

### **5.1 Abstract:**

The unavailability of effective FAW control measures in Africa is a serious threat to food insecurity for smallholder farmers. The invasion of FAW in Africa since 2016 has resulted in excessive use of pesticides many of which are detrimental to the environment, livestock and the untrained farmers. FAW's ability to quickly resist pesticides means that the problem it causes will remain for a long period. The objectives of the study were to find the effect of maize variety and time of planting on FAW attack. In an effort to find sustainable solutions for the control of FAW, a 4X3 factorial experiment in randomised blocks replicated 3 times was used to evaluate resistance to damage by FAW of 4 maize varieties planted over 3 dates. Evaluation for kernel damage score, exit holes, yield (t/ha) and discard (t/ha) (as a result of FAW damage) was used to determine the effect of maize variety and planting dates at 4 maize growth stages. Varieties used were DKC8053, SC 649, SC 633 and SC 637. The maize growth stages evaluated were V5, V8, VT and R5. The maize varieties were planted over 3 planting dates of early planting (15 Nov), mid season planting (15 Dec) and late planting (28 Dec). Analysis of variance for yield (t/ha), discard %, kernel average score (KAS), average exit holes (AEH) were done using Gernstart release 16.

All measured parameters except exit holes showed time of planting dependence. Early planting resulted in the least damage on kernel by FAW while late planting received the greatest damage. Variety effect was not significant against FAW attack. The interaction of time of planting and variety was not significant in mitigating against FAW attack. Early planting also resulted in greater yield (3.93t/ha) than late planting (1.77t/ha). The greatest discard as a result of FAW damage was observed in late planting (30.93%) compared to early planted crop (10%). Early planting had the least score on kernel damage (1.22) while late and mid season planting had the highest score of 4.38. Early planting showed effectiveness in mitigating against FAW damage and can be used as a sustainable solution where FAW is not endemic.

#### **Key words:**

- Average exit holes (AEH),
- Kernel average score (KAS),
- yield (t/ha),
- discard % and time of planting.

### 5.3 Introduction

Reduction of corn yield caused by FAW can reach 60% depending on the genotype and growth stage of the plant where the damage was caused (Cruz, et al , 2008). In Africa the control of FAW is mainly through the use of chemical insecticides that have an adverse effect on the environment which may promote the selection of resistant insects (lima et al, 2006). The use of host plant resistance (HPR) provides an alternative and sustainable option for the control of FAW in the maize crop. Use of insect resistant crop varieties has economic, ecological and environmental benefits. The choice of planting date is usually determined by many factors such as weather, labour availability and many more. Growers should consider a planting date to grow the crop outside the pest window especially for key pests such as the FAW. Time of planting is one of the most important cultural practices employed widely in southern states to control damage by earworms (Mitchell, 1998).

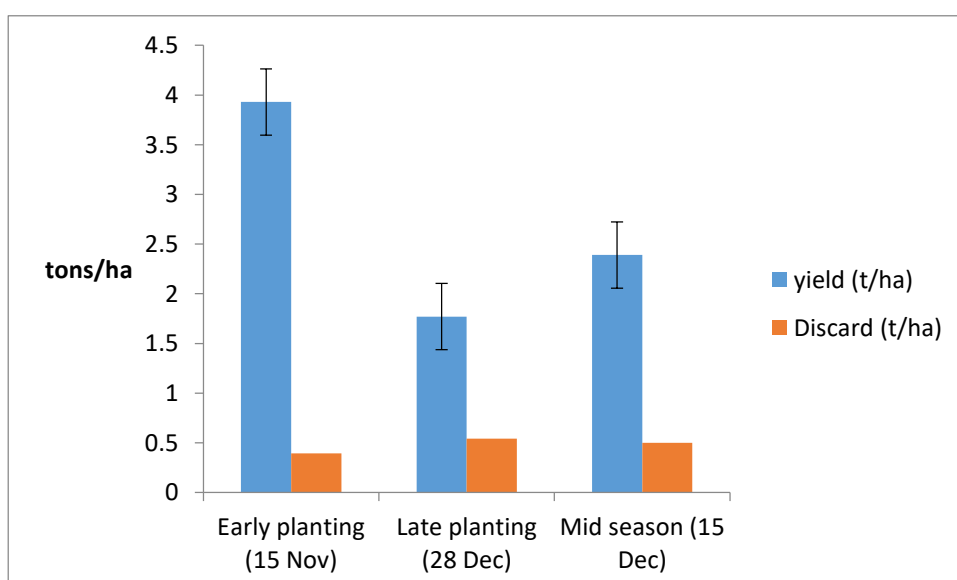
### 5.4 Materials and Methods

**NB Refer to 3.1 to 3.for sections 5.2 to 5.2.6**

### 5.3 Results:

#### 5.3.1 Yield Analysis:

Variety had no significant effect on yield at  $p < 0.05$  on observed treatments. Time of planting had a significant effect on yield on observed treatments at  $p < 0.05$ . There was no effect on yield due to variety-time interaction. Early planting had the highest yield of 3.93t/ha while late planting had the least yield of 1.77t/ha. Yield for mid season planting was 2.39t/ha. Late and mid season planting performed the same in terms of yield while early planting was outstanding; Fig 7 below shows yield analysis on observed treatments.



**Yield (t/ha)**  
**Analysis:**

### Fig7: Yield (t/ha) and discard as a result of FAW attack

#### 5.3.2 Discard due to FAW damage (%):

Variety had no significant effect on % discard as a result of FAW attack at  $p < 0.05$ . Time of planting had significant effect on discard on observed treatments at  $P < 0.05$ . Variety-time interaction had no significant effect on discard. Early planting had the lowest mean of 10% discard while late planting had the highest mean of 30.6%. Mid season planting had 20.9 % discard. Early planting had the least discard while mid season and late planting which were ranked the same at 20.93 and 30.64 at  $p, 0.05$ . Fig 8 shows graph of discard as a result of FAW.

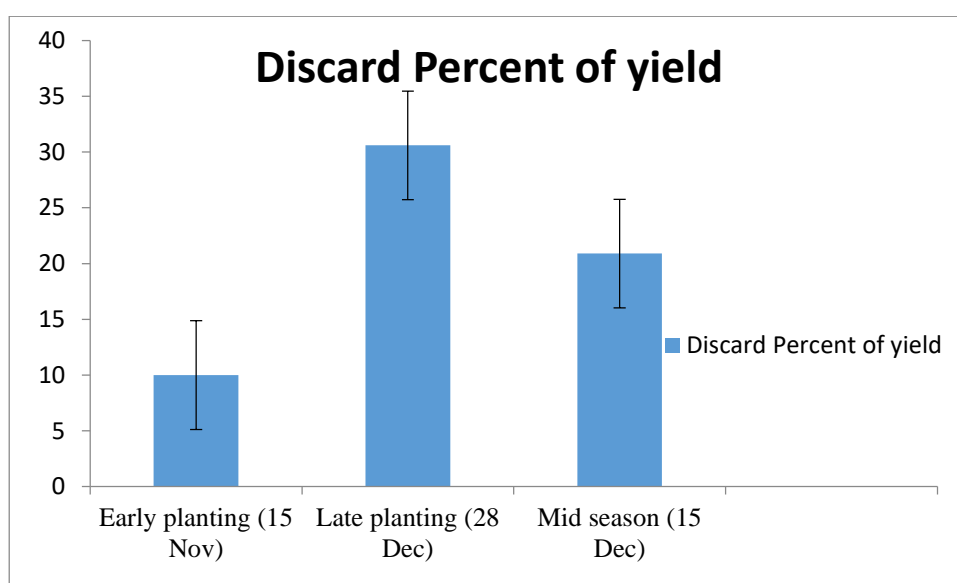


Fig 8: discard percent of total yield.

#### 5.3.3 Effect of maize variety on average exit holes (AEH)

There was no significant effect of variety on AEH at  $p < 0.05$ . Variety 2 had the least score of 2.93 while variety four had the highest score of 3.51. Variety 1 and 3 had 3.33 and 3.44 respectively.

#### 5.3.4 Effect of time of planting on average exit holes (AEH)

There was no significant effect of time at  $p < 0.05$  on observed treatments. There was no significant effect of variety –time interaction on AEH at  $p < 0.05$ .

#### 5.3.5 EFFECT OF FAW ON KERNEL DAMAGE

##### 5.4.6 Kernel Average Score (KAS)

There was no significant effect of variety on kernel average score at  $p < 0.05$ . There was significance influence of time on KAS at  $p < 0.05$ . Variety –Time interaction was significant on KAS at  $p < 0.05$ .

There was however no significance difference between mid season planting and late season planting on kernel score. There was significant difference between late and early planting. Early planting had the least score of 1.22. Mid season planting had the highest score of 4.38. Early planting was different from the rest while mid and Late planting were ranked the same.

Fig 9 below shows average kernel score for early and late planting.

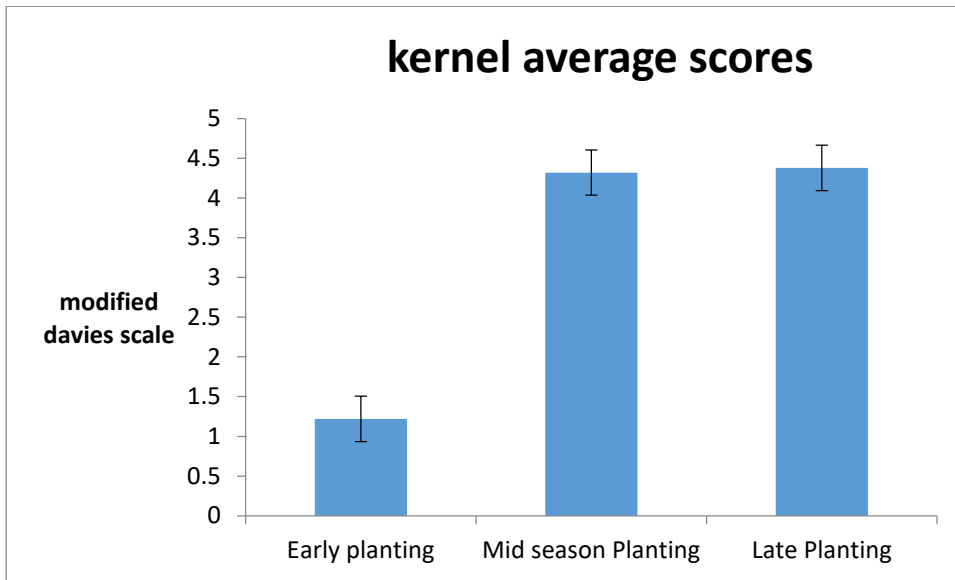


Fig 9: Average kernel score (Modified Davies Scale)

The following plates shows results in picture form for observed parameters.

### 5.5 Results in Picture form

Plate 2 and 3 below shows the extend of leaf damage on early (left) and late crops (right)



Plate 2 (early crop)



Plate 3 (late crop)



Plate 4



Plate 5

Plate 4 & 5 above shows stem damage and exit holes caused by FAW.

**5.5.1 Effects of FAW attack on kernel damage on late planting compared to early planting**



Plate 6

Plate 6 above shows early crop right compared to late crop left for DKC 8053

Plate 6 early crop (left and late crop (right)



**Plate 7 Late crop**



**Plate 8 Early crop**



**Plate 9 Late crop**



**Plate 10 Early crop**



**Plate 11 Late crop**

**plate 12 early crop**

Plates 6 to 13 above

**5.5.2 Comments on plates shown above**

Plates 6 to 13 above shows the effect of time of planting and maize variety on FAW attack. Late planting was done on 28 December while early planting was done on 15 November.

Below is a summary table showing results for measured parameters at R5 stage :

### 5.5.3 Summary results on measured parameters at R5 stage:

Variety/planting time	LAS	NO. Affected %	AEH	KAS	Yield(t/ha)	Discard(% of yield)
Variety 1	1.93n/s	49.4n/s	0.280n/s	3.33n/s	2.57n/s	23.7 n/s
Variety 2	1.99n/s	56.3n/s	0.358n/s	2.93n/s	2.76n/s	19.0 n/s
Variety 3	2.02n/s	48.9n/s	0.560n/s	3.44n/s	2.65n/s	22.9 n/s
Variety 4	2.16n/s	59.9n/s	0.527n/s	3.51n/s	2.80n/s	16.4 n/s
Early	1.73a	21.00a	0.650n/s	1.217a	3.93b	10.00a
Mid season	1.83a	56.50b	0.480n/s	4.317b	2.387a	20.93b
Late Planting	2.50b	83.42c	0.163n/s	4.379b	1.768a	30.64b
<b>Grand Mean</b>	<b>2.02</b>	<b>53.6</b>	<b>0.431</b>	<b>3.30</b>	<b>2.70</b>	<b>20.3</b>
<b>Cv%</b>	<b>6.7</b>	<b>16.1</b>	<b>38.2</b>	<b>17.4</b>	<b>14.5</b>	<b>8.9</b>
<b>LSD (time)</b>	<b>0.502</b>	<b>10.56</b>	<b>0.4468</b>	<b>0.591</b>	<b>0.690</b>	<b>10.10</b>
<b>Se</b>	<b>0.110</b>	<b>7.06</b>	<b>0.1346</b>	<b>0.469</b>	<b>0.320</b>	<b>1.83</b>
<b>P- Value</b>	<b>0.05</b>	<b>0.05</b>	<b>0.05</b>	<b>0.05</b>	<b>0.05</b>	<b>0.05</b>
<b>LSD(variety)</b>	<b>0.580</b>	<b>12.19</b>	<b>0.5160</b>	<b>0.682</b>	<b>0.797</b>	<b>11.66</b>
<b>LSD(variety-Time)</b>	<b>1.004</b>	<b>21.12</b>	<b>0.8937</b>	<b>1.181</b>	<b>1.380</b>	<b>20.20</b>

Table 6 Summary Results on Measured parameters

### 5.6. Discussion:

Time of planting was significant for all observed treatments at  $P < 0.05$ . Yield (t/h), % discard, and Kernel average score all showed time dependence. This was however not the case for average exit holes which was high in the early crop than in mid and late crops. The high kernel damage of late crops and the relatively low number of exit holes in the late crop may be indicative of feeding preference and pupation may have occurred in maize husks rather than in stems. FAW can pupate in the soil and in maize husks in addition to the stem of the maize plant and therefore the number of exit holes may not be indicate of infestation levels..

Time of planting shows significance for most of the measured parameters. Results obtained could be as a result of the low temperatures which are experienced during winter in Kandava village.

Temperatures can go as low as 8 degrees Celsius. Very low temperatures results in the death of pupa stage and migration of the adult moth to favourable environments. Pitre and Hogg, 1983 noted that pupae stage of FAW cannot withstand protracted periods of cold weather. Results obtained are also in line with the findings of Heerden, 2018 who noted that later plantings tend to show a more uniform distribution and higher level of damage. Mwangi, 2018 also noted that early planting i.e. at the start of the rains avoid peak migration of the FAW adult moth. Mwangi also recommended the avoidance of staggered plantings as later crops tend to be damaged more. Early planting also results in plants obtaining more heat units and attaining faster growth rates and more yield. Fast growth rate as a result of heat units enables the pest to escape pest damage at vulnerable growth stages.

The effect of maize variety was not significant on all observed treatments. The maize hybrids used could have emanated from the same parent and therefore could have similar genetics for pest resistance. It is important to note that 3 of the maize hybrids were from the same seed company and the possibility of them emanating from the same parent are high. Results confirm the findings of Mc Million et al, 1977 who noted that there are few corn varieties which can withstand earworms and FAW attack. Goergen, et al, 2016 also noted that breeding for FAW resistance has only been initiated in Africa and therefore there are no current African varieties which can withstand FAW attack. This was also in line with the comments of Prasanna, et al, 2018 who noted that there are no Africa adapted maize varieties with scientifically validated resistance to FAW. This gap is currently being addressed by the International Maize and Wheat Improvement Centre (CIMMYT) who are evaluating several germplasm for FAW resistance, (Prasanna, 2018).

### **5.7 Recommendations:**

Early planting should be used to mitigate damage from FAW in areas like Mashonaland East where FAW has a migratory habit. It is also important to note that farmers who farm in endemic areas (where FAW is always available all year round) may not benefit from the strategy of planting early as the pest is always present in greater numbers. Control of FAW using cultural practices such as early planting is therefore site specific.

**5.8 Conclusions:**

Time of planting has proved to be significant for all the measured parameters of kernel average score, (KAS), yield (t/ha), discard %. For key insects pests like the fall armyworm growers should consider a planting date to grow the crop outside the pest window especially in non endemic regions where FAW exhibits a migratory habit. Early planting proved to be effective in mitigating damage by FAW such areas.

## CHAPTER 6

### SUMMARY, CONCLUSION AND RECOMMENDATIONS

#### 6.1 INTRODUCTION

Teeths, 2017 defined plant resistant is as the consequence of heritable plant qualities that result in a plant being relatively less damaged than a plant without the qualities. Plant resistance to insects is one of several cultural control methods (Teethes, 2017). Cultural control methods involve use of agronomic practices to reduce insect pest abundance and damage below that which would have occurred if the practice had not been used. Use of insect resistant crop varieties is economically, ecologically, and environmentally advantageous (Teeths,2017). Reduction in the productivity of corn caused by FAW can reach 60% depending on the genotype and growth stage of the plant where the damage was caused (Crue et al, 2008). The control of FAW has been achieved mainly through the use of pesticides which have an adverse effect on the environment and may promote the selection of resistant insects (Lima et al, 2006). Extensive resistance to *S.fragiperda* has been done and a series of corn germplasm lines conferring *S.frugiperda* resistance have been developed at Mississippi State, for the southern States (Brooks et al, 2007) and Tilton Gab (Wiseman et al, 1996)

The resistant mechanism in maize occurs via antibiosis when the negative effects of a resistant plant affect the biology of the insect pest utilising the plant as a host, (Smith, 2005). The effects of an antibiotic plant may range from mild to lethal and are the result of either chemical or morphological plant defences (Smith, et al 2005).

Antixenosis is characterized by the presence of morphological or chemical plant factors that adversely alter insect behaviour. This result in the insect searching for an alternate host plant. (Smith, 2005, Seifi et al, 2013).

The invasion of Africa by FAW caught many small holder farmers unaware. Currently the most common control measure is through the use of pesticides which are however detrimental to the environment, the farmer and livestock.

Currently there are no known African varieties which resist FAW attack. Selection for FAW resistant germplasm has recently started and is being spear headed by cimmyt, (.Prasanna et al , 2018)

## 6.2 Research Summary

Four maize varieties commonly grown in Zimbabwe were evaluated for FAW resistance.

The effect of the 4 maize varieties in resisting FAW attack was reflected in an appreciable non significant relationship on all the measured parameters of leaf damage score, average exit holes (AEH), average kernel score, (AKS), yield (t/ha), percent discard as a result of fall armyworm attack and on the number of plants affected by fall armyworm. (Table 1, chapter 3). The four mid seasons hi breeds did not offer significant resistance to FAW attack. It is possible that the maize hi breeds used in this experiment could have originated from the same parent and has similar genetics for pest resistance and hence the similarity in performance when subjected to fall armyworm attack... Three of the maize varieties used in this experiment were from the same seed company. Mc Million et al, 1977 also discovered that there are few commercial sweet corn varieties which possess a superior degree of resistance to earworms and fall armyworms. Breeding for FAW resistance have only been recently initiated in Africa (Goergen et al, 2016). .Prasanna et al, 2018, also noted that there are no African –adapted maize cultivars with scientifically validated resistance to FAW. This gap is currently being addressed by the International Maize and Wheat improvement Centre (CIMMYT) who is evaluating several maize germplasm (.Prasanna, 2018). The fact that the experiment was carried under natural infestation may have influenced the outcome. Natural infestation makes it difficult to achieve sufficient uniformity in the distribution among the varieties. This is because the insects are prone to escape or there may be excessive infestation or differential attraction (Prasanna, 2018).

It may therefore be possible that host plant resistance is present in the four commercial hybrids used, but maybe inadequate for complete protection. Capinera, 2017, noted that partial resistance is present in corn varieties which however are inadequate for complete protection against fall armyworm.

### **6.3 The effect of time of planting on FAW attack:**

Time of planting showed significant effect on all the measured parameters except for average exit holes (AEH). Leaf average score (las), number of plants affected, kernel average score, yield (t/ha ) as well as discard as a result of fall armyworm attack and the subsequent secondary infection on grain all showed time dependence. Late planting of maize is detrimental to fall armyworm attack Mashonaland East. This is probably due to the fact that winter temperatures are very low (min of 8 degrees Celsius and max of 26 degrees Celsius). Low temperatures during winter results in the death of the pupa stage and or migration of the adult moth of the FAW to favourable environments. Pitre & Hogg, 1983, noted that pupae stage of fall armyworm cannot withstand protracted periods of cold weather. It is possible that the moths will only come back during warmer summer months and will proliferate catching late planted crops at vulnerable stages while early planted crops will have escaped. The results obtained are in line with the findings of (Heerden, 2018) that discovered that later plantings tend to show a more uniform distribution and higher levels of damage. (Mwangi, 2018) , also noted that early planting i.e. at the start of the rains avoids peak migration of FAW adult moths. He also encouraged farmers to avoid late and off season plantings. F.M. Davis and (William, 1992), also recommended timely planting among many measures to mitigate damage by fall armyworm. (William, 1992), Davis et al, 1996 asserted that *S. frugiperda* is the most important whorl feeding insect pest especially in late planted corn. Time of planting dictates whether or not a pest will be in sufficient numbers to become a problem ( Phillips, 2005). ( Phillips, 2005) noted that corn earworms on sweet corn is less of a problem in early planted crops. Planting early with the first rains avoids FAW populations build up later in the season. Planting at different times also provides FAW with a continuous source of food (CABI, 2018). Early planting has also been recommended by Gebre- Mlak et al, (1989 and Van dan Berg and Van Rensburg , 1991), who showed evidence with stem borers which showed that timely planting has higher chances of escaping pest infestation compared to delayed planting. Early crops can grow fast as a result of experiencing more heat units resulting in escaping pest attack at vulnerable stages.

It is also important to note that discard as a result of fall armyworm attack and the subsequent secondary infection of grain by parasitic moulds was highest in the late planted crop (30.64%) than in the early planted crop which had 10% of the yield as discard. This pattern could be as a result of feeding preference of the FAW as soft kernels and silk of the late crop were preferred.

There was evidence of interfering with pollination processes by the FAW as most kernels of late crops showed lack of pollination and synchronization. Field observations showed a complete shift of preference as the FAW preferred the soft tissue of the late crop. Growth vigour (not measured) for late and mid season planting was slow and all four varieties had high levels of maize smut and strike virus. In some incidences there was complete death of affected plants as a result of FAW attack.

#### **6.4 Effect of the interaction of planting time and maize variety in mitigating on fall - armyworm attack:**

The interaction of planting time and the 4 maize varieties was not significant in mitigating against fall armyworm attack. All the measured parameters except kernel average score showed no significant effect. There was however significant effect on interaction of time of planting and maize variety on kernel average score. Varieties 1 , 2, 3 and 4 showed similar effect with early planting while there was significant difference between early planting and late planting as well as mid season planting. Late planting of variety 3 had the highest kernel score of 5.47 followed by mid season planting of variety 4 with a score of 5.38. Varieties 1 and 2 had the least score of 1.13. Fall army worm attack was more severe in late planting of variety 3 and mid season planting of variety 4 respectively. Varieties 3 and 4 also had the highest leaf score indicating high vulnerability to FAW attack than the other varieties. Farmers are encouraged to plant varieties 1 and 2 early to get the least damage from fall armyworm. Extension personnel should study the population dynamics of FAW to properly advise farmers of the correct planting date in their area.

#### **6.5 Conclusion:**

The four commercial maize hybrids commonly grown in Kandava village did not show significant fall army resistance for all measured parameters which included leaf damage, plants affected, exit holes, kernel damage yield and discard. Time of planting however showed significant effect on all measured parameters except for exit holes. Farmers should therefore plant their maize crop ideally by 15 November or with the first effective rains to avoid greater FAW damage. Late planting results in more yield losses due to discard as a result of parasitic moulds feeding on kernels following FAW damage.

#### **6.6 Recommendations:**

Fall armyworm control strategies should be site specific and early planting is important in areas where FAW has a migratory habit. Lessons should be drawn from experience obtained from countries where FAW originated including. The

**6.7 Policy implications:**

Governments in SSA should ensure that farmers plant early by making available affordable inputs through the provision of subsidies. More funding should be channelled into research and extension to speed up efforts of finding lasting solutions to the FAW challenge in Zimbabwe.

**6.8. Areas for further Research:**

More germplasm should be screened for FAW resistance from diverse sources to avoid use of material from the same parents. Sustainable and environmental friendly control methods of fall armyworm such as the proliferation of biological control agents should be looked into. Breeding and proliferation of FAW natural enemies should be considered.

## 6.8 References

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## 6.9 APPENDICES

### 6.9.1 APPENDIX A

#### 6.9.1. Damage by FAW in late planted crop compared to early crop below

Late planted crop (28 December)



Plate 13



Plate 14



Plate 15



Plate 16

Plates 13 to 16 above shows late planted crop (28 December)

Plates 17 to 20 below shows early planted crop kernels compared to late plated crop above (plate 13to 16)



Plate 17



Plate 18

Early crop (15 November)



Plate 19



Plate 20

Early crop (15 November)

**There is noticeably less damage to the early planted crop compared to late crop an observation which mirrors results on data analysed.**

## 6.9.2 Appendix B

### 6.9.3 Maize growth stages

<b>Days</b>	<b>Description</b>	<b>Stage</b>
0	Planting	
7	Emergence	Ve
14	Two leaves fully emerged	V2
28	8 leaves fully emerged	V8
42	12,16,20 leaf stage	V12
56	Late whorl stage	VT
66	Teaselling/silking	R1
70-100	Maturity	R5

Table 7 Maize growth stages

Source fall armyworm IPM guide- 2019

Table6.Maize growth stages (Modified from Clarrie Beckingham, 2007, <https://www.dpi.nsw.gov.au/agriculture/horticulture/vegetables/commodity-growing-guides/sweet-corn>).

## 6.9.3 APPENDIX C

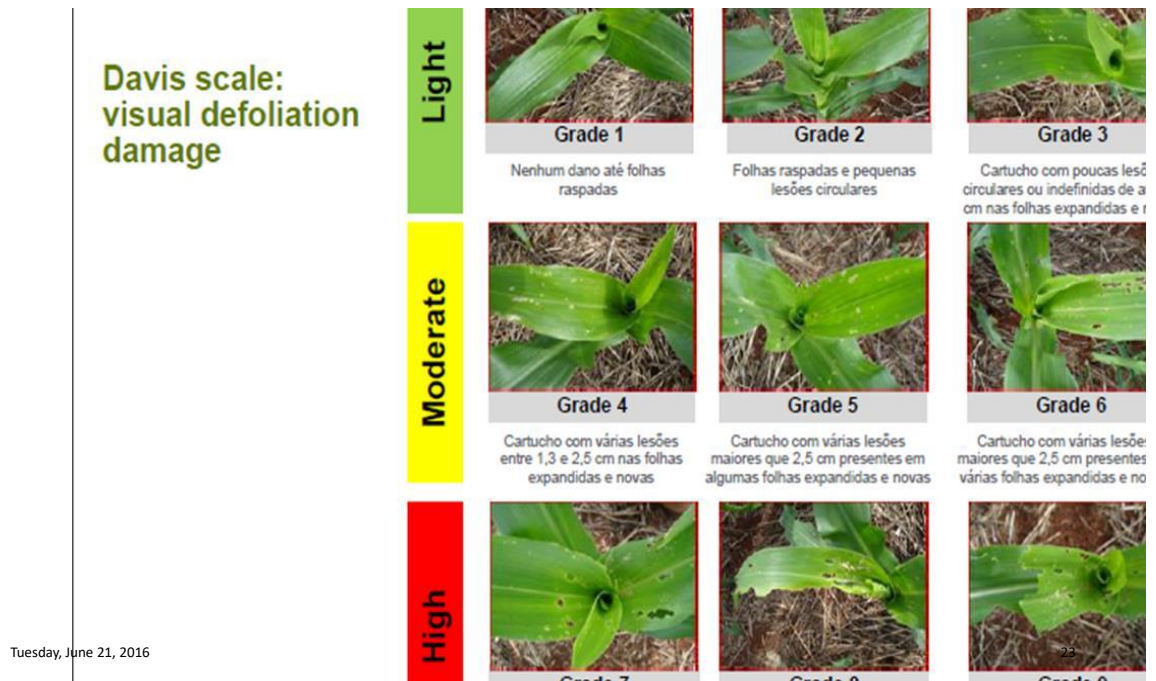
### 6.9.4 Yield potential for varieties

<b>Variety</b>	<b>Yield obtained (t/ha) under no FAW control</b>	<b>Maximum genetic potential yield (t/ha)</b>
<b>SC633</b>	<b>2,65</b>	<b>14</b>
<b>SC637</b>	<b>2.8</b>	<b>16</b>
<b>SC649</b>	<b>2.76</b>	<b>16</b>
<b>DKC8053</b>	<b>2.57</b>	<b>14</b>

Table 8 Yield Potential for maize varieties used in the experiment

## 6.9.5 APPENDIX D

### 6.9.6 Foliar Ratings



**G1** Scale for assessment of foliar damage due to FAW in maize germplasm entries. Score  
Damage symptoms/description Response

- 1 No visible leaf-feeding damage highly resistant
- 1 Few pinholes on 1-2 older leaves Resistant
- 2 3 Several shot-hole injuries on a few leaves (<5 leaves) and small circular hole damage to leaves Resistant
- 3 4 Several shot-hole injuries on several leaves (6–8 leaves) or small lesions/pinholes, small circular lesions, and a few small elongated (rectangular-shaped) lesions of up to 1.3 cm in length present on whorl and furl leaves Partially resistant

- 4 5 Elongated lesions (>2.5 cm long) on 8-10 leaves, plus a few small- to mid-sized uniform to irregular-shaped holes (basement membrane consumed) eaten from the whorl and/or furl leaves Partially resistant
- 5 6 Several large elongated lesions present on several whorl and furl leaves and/or several large uniform to irregular-shaped holes eaten from furl and whorl leaves Susceptible
- 6 7 Many elongated lesions of all sizes present on several whorl and furl leaves plus several large uniform to irregular-shaped holes eaten from the whorl and furl leaves Susceptible
- 7 8 Many elongated lesions of all sizes present on most whorl and furl leaves plus many mid- to large-sized uniform to irregular-shaped holes eaten from the whorl and furl leaves Highly susceptible
- 8 9 Whorl and furl leaves almost totally destroyed and plant dying as a result of extensive foliar damage Highly susceptible

Source: Modified from Davis and Williams (1992).

## 6.9.7 APPENDIX E

### 6.9.8 Germplasm ratings based on ear and kernel damage by FAW.

#### Score Damage symptoms/description Response

Rating score	Description	comment
1	No damage to the ear	Highly resistant
2	Damage to a few kernels (<5) or less than 5% damage to an ear	Resistant
3	Damage to a few kernels (6-15) or less than 10% damage to an ear	Resistant
4	Damage to 16-30 kernels or less than 15% damage to an ear	Partially resistant
5	Damage to 31-50 kernels or less than 25% damage to an ear	Partially resistant
6	Damage to 51-75 kernels or more than 35% but less than 50% damage to an ear	Susceptible
7	Damage to 76-100 kernels or more than 50% but less than 60% damage to an ear	Susceptible
8	Damage to more than 100 kernels or more than 60% damage to an ear	Highly susceptible
9	Almost 100% damage to an ear	Highly susceptible

## Table 9 Kernel Damage ratings for maize varieties

Source: CIMMYT unpublished protocol.

### 6.9.9 APPENDIX F

#### 7.0 V5 Maize Growth Stage

##### 7.1 Analysis of variance

Variate: LAS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.1267	0.0633	0.14	
Block.*Units* stratum					
Time	2	2.5267	1.2633	2.77	0.085
variety	3	0.4267	0.1422	0.31	0.817
Time.variety	6	1.5267	0.2544	0.56	0.759
Residual	22	10.0333	0.4561		
Total	35	14.6400			

### 7.2 APPENDIX G

#### 7.2.1 V8 Maize growth stage:

##### 7.2.1 Analysis of variance

Variate: LAS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.3889	0.1944	0.99	
Block.*Units* stratum					

variety	3	1.8789	0.6263	3.20	0.043
Time	2	1.8022	0.9011	4.61	0.021
variety.Time	6	1.6644	0.2774	1.42	0.252
Residual	22	4.3044	0.1957		
Total	35	10.0389			

### 7.3 APPENDIX H

#### 7.3.1 VT Maize growth stage

#### 7.3.2 Analysis of variance

Variate: LAS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.8600	0.4300	0.75	
Block.*Units* stratum					
variety	3	1.2711	0.4237	0.74	0.539
Time	2	4.5067	2.2533	3.94	0.034
variety.Time	6	1.5822	0.2637	0.46	0.829
Residual	22	12.5800	0.5718		
Total	35	20.8000			

### 7.4 APPENDIX I

#### 7.4.1 R5 Maize growth stage

#### Analysis of variance

Variate: LAS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	3.5756	1.7878	1.83	
Block.*Units* stratum					
Time	2	64.9689	32.4844	33.21	<.001
variety	3	1.4489	0.4830	0.49	0.690
Time.variety	6	0.8978	0.1496	0.15	0.986

Residual	22	21.5178	0.9781
Total	35	92.4089	

## 7.5 APPENDIX J

### 7.5.1 Analysis of variance

#### 7.4.2 Variate: %\_plants

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	1793.6	896.8	5.76	
Block.*Units* stratum					
Time	2	23522.4	11761.2	75.60	<.001
variety	3	778.3	259.4	1.67	0.203
Time.variety	6	1169.6	194.9	1.25	0.319
Residual	22	3422.4	155.6		
Total	35	30686.3			

## 7.5 APPENDIX K

### 7.5.1 Analysis of variance

#### 7.5.2 Variate: yield\_t\_ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	3.6890	1.8445	2.78	
Block.*Units* stratum					
Time	2	29.7728	14.8864	22.42	<.001
variety	3	0.2982	0.0994	0.15	0.929
Time.variety	6	3.5815	0.5969	0.90	0.513
Residual	22	14.6100	0.6641		
Total	35	51.9515			

## 7.6 APPENDIX L

### 7.6.1 Analysis of variance

#### 7.6.2 Variate: %\_discard

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	80.5	40.2	0.28	
Block.*Units* stratum					
Time	2	2558.8	1279.4	8.99	0.001
variety	3	315.8	105.3	0.74	0.540
Time.variety	6	1124.6	187.4	1.32	0.291
Residual	22	3131.1	142.3		
Total	35	7210.8			

## 7.7 APPENDIX M

### 7.7.1 Analysis of variance

#### 7.7.2 Variate: KAS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	7.9062	3.9531	8.13	
Block.*Units* stratum					
Time	2	78.4612	39.2306	80.63	<.001
variety	3	1.7944	0.5981	1.23	0.323
Time.variety	6	9.5628	1.5938	3.28	0.019
Residual	22	10.7038	0.4865		
Total	35	108.4285			

## 7.8 APPENDIX N

### 7.8.1 Analysis of variance

#### 7.8.2 Variate: AEH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.6520	0.3260	1.17	
Block.*Units* stratum variety	3	0.4856	0.1619	0.58	0.634
Time	2	1.4641	0.7320	2.63	0.095
variety.Time	6	0.6544	0.1091	0.39	0.876
Residual	22	6.1280	0.2785		
Total	35	9.3842			

## 7.9.APPENDIX O

### FALL ARMYWORM LIFE CYCLE

#### 7.9.1 FAW life cycle

Below is the life cycle of FAW

## FAW Life cycle

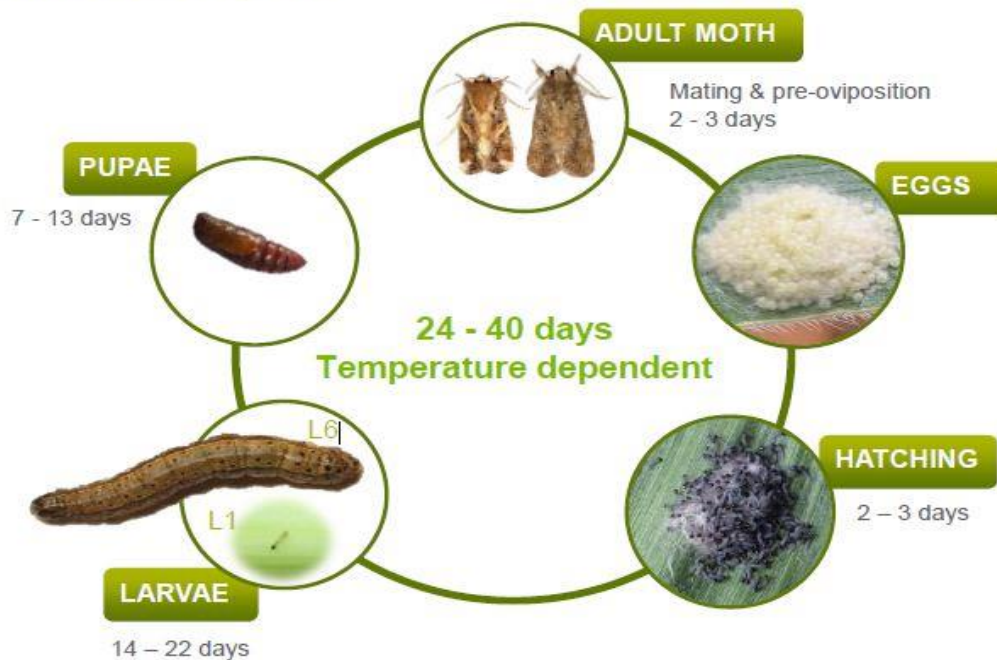


Fig 1

Source: Syngenta, 2018

### 7.9.2 Description of life cycle:

The Life cycle of FAW varies from 30 days to 90 days depending on prevailing temperatures. The pest completes its life cycle in 30 days when temperatures are around 28 degrees during warm summers. Life cycle may extend to 60-90 days when temperatures are cool. FAW does not have the ability to diapause (biological resting period) and as a result infestations may occur throughout the year where the pest is endemic. The pest arrives seasonally in non endemic areas and comes when conditions become favourable during warm summers. Only one generation may be obtained before pest becomes locally extinct in non endemic areas. FAW is endemic in natural region 4 and 5 of Zimbabwe) and only arrives by migration to the cooler highland areas such as Agro ecological region 1 and 2. FAW eggs are deposited in layers, but most eggs are spread over a single layer attached to foliage. The number of eggs per moth varies considerably. Total egg production per female is greater than 2000. Eggs may be covered or not covered. Eggs hatch in 2 to 3 days during warm summer.

### **7.9.3. Larval Stage**

FAW has six larval instars. Young larvae are greenish with a black head. The colour of FAW larva turns to a more orange colour in the second instars. Head capsule widths range from about 0.3 mm (instar 1) to 2.6 mm (instar 6), and larvae attain lengths of about 1 mm (instar 1) to 45 mm (instar 6). In the second instar, but particularly the third instar, the dorsal surface of the body becomes brownish, and lateral white lines begin to form. In the fourth to sixth instars the head is reddish brown, mottled with white, and the brownish body bears white subdorsal and lateral lines. Elevated spots occur dorsally on the body; they are usually dark in colour and bear spines. The face of the mature larva may also be marked with a white inverted “Y” and the epidermis of the larva is rough or granular in texture when examined closely. In addition to the typical brownish form of the FAW larva, the larva may be mostly green dorsally. In the green form, the dorsal elevated spots are pale rather than dark. The best identifying feature of the FAW is a set of four large spots that form a square on the upper surface of the last segment of its body (Figure 2). Larvae tend to conceal themselves during the brightest time of the day. Duration of the larval stage tends to be about 14 days during the warm summer months and 30 days during cooler weather. Mean development time was determined to be 3.3, 1.7, 1.5, 1.5, 2.0, and 3.7 days for instars 1 to 6, respectively, when larvae were reared at 25°C (Pitre and Hogg 1983).

FAW LARVA



Plate 1 larva

#### Damage caused:

The 1<sup>st</sup> instar makes small windows on leaf surface of the maize crop. Infestations often go unnoticed. Larvae feed for 2 to 3 weeks. Full grown larva is 2, 5-3.8 cm. It produces trash or excrement which forms dry dust. Larvae of FAW have great appetite and consume 80% of total food intake in the last few days. Larvae damages both vegetative and reproductive parts of the maize plant.

#### **7.9.4 Pupal Stage**

The FAW normally pupates in the soil at a depth 2 to 8 cm. Pupation can also occur in Stover of maize plants. The larva constructs a loose cocoon by tying together particles of soil with silk. The cocoon is oval in shape and 20 to 30 mm in length. If the soil is too hard, larvae may web together leaf debris and other material to form a cocoon on the soil surface. Pupation can also occur in leaf sheath, stems or ears. The pupa is reddish brown in colour, measuring 14 to 18 mm in length and about 4.5 mm in width. Pupa stage duration is about 8 to 9 days during the summer, but reaches 20 to 30 days during cooler weather. The pupa stage of FAW cannot withstand protracted periods of cold weather. For example, Pitre and Hogg (1983) studied winter survival of the pupa stage in Florida, and found 51% survival in southern Florida, but only 27.5% survival in central Florida and 11.6% survival in northern Florida. This range is

approximately between 25.1°N to 30.3°N latitude and represents a January (winter) temperature range of 18-24°C (Capinera, 1999).

7.9.5 Adult Stage Moths of adult FAW have a wingspan of 32 to 40mm. Forewing of male moth is shaded gray and brown with triangular white spots at the tip and near the centre of the wing. Forewings of females are less distinctly marked, ranging from a uniform greyish brown to a fine mottling of gray and brown, (Ashley et al 1989). Both sexes have a hind wing which is iridescent silver-white with a narrow dark border. Adults are nocturnal, and are most active during warm, humid evenings. After a preoviposition period of 3 to 4 days, the female moth normally deposits most of her eggs during the first 4 to 5 days of life, but some oviposition occurs for up to 3 weeks. Duration of adult life is estimated to average about 10 days, with a range of about 7-21 days.

#### **7.9.6 Hosts plants:**

FAW is highly polyphagous and feeds on over 80 crops. Larvae prefer maize/corn and sweet corn. Plant parts attacked include seedlings to grain ready for harvest. Can cut stems below surface like cutworm or cause dead hearts in plants.