

**FARMER EVALUATION OF FORTENZA DUO TECHNOLOGY IN THE CONTROL
OF FALL ARMYWORM IN ZAMBIA.**

BY

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A dissertation submitted to the University of Zambia in partial fulfillment of the requirements for the award of a Masters' Degree in Agricultural Economics.

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ABSTRACT

The arrival of Fall Army Worm (FAW) in Africa and Zambia specifically has made the situation worse for the farmers who already experience low crop productivity. However, Syngenta developed an insecticide called Fortenza duo, a seed coating pesticide which according to the company can protect crops from FAW attack in the first 30 days after germination. Fortenza duo can therefore help to reduce farmers' financial costs and labour demand. However, no study has been conducted in Zambia to evaluate the efficacy of Fortenza duo on farmer fields. Before rolling out and encourage the farmers to adopt this technology in the country, it's important to carry out farmer evaluation of fortenza duo technology to assess its effectiveness, and that was the aim of the study. The objectives of the study were: To assess farmers' preference for Fortenza duo treated maize as compared to other non-treated hybrid and local varieties; to assess the criteria farmers consider important when choosing pesticide; and to evaluate the effectiveness of fortenza duo technology in controlling FAW in farmers' crop fields. A survey was conducted with 153 treatment farmers and 162 control farmers, and a follow-up was done to a subset of 35 treatment farmers. A participatory survey was conducted with 202 farmers to evaluate the maize demonstration plots, and another survey was conducted with 44 farmers invited to evaluate a maize trial treated with fortenza duo. The study used descriptive and statistical analyses, including ordinal and mixed regression analysis. The results showed that Fortenza duo is effective in controlling FAW attack to maize. Using fortenza duo will delay FAW attack by over 2 weeks as compared to non-treated seeds, statistically significant at p-value 0.0001. The severity of the infestation will also be minimal with fortenza treated seeds. Fortenza duo is also socially, economic and environmentally suitable to the farmers in terms of reduced labour, cost, health risk, and it's convenient to use. Treated maize with fortenza duo is also preferred to untreated maize in terms of vigor, stalk thickness, cob size, grain size and yield. Based on the effectiveness, fortenza duo technology should be encouraged for adoption to the farmers for the prevention of FAW in Zambia.

Key words: FAW, Fortenza duo, Evaluation, Effectiveness, Ordinal regression, Mixed regression

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Above all, I give Glory to JEHOVAH GOD for His Blessings.

DEDICATION

I dedicate this thesis to my late mother, Annie Bwalya; for providing me with education and for all the love, support and encouragement she gave to me. I will forever be grateful to you Mum and thank God Almighty for you and everything in my life.

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ABBREVIATIONS

CABI:	Centre for Agriculture and Bioscience International
CIMMYT:	International Maize and Wheat Improvement Centre
DFID:	Department for International Development
FAO:	Food and Agriculture Organisation
FAW:	Fall army worm
FD:	Fortenza Duo
IITA:	International Institute for Tropical Agriculture
IPPC:	International Plant Protection Convention
SADC:	Southern African Development Community

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Chapter one gives an introduction to the research study, it gives background information on fall armyworm (FAW), the origin and spread of FAW in Africa and its devastating effect on crops. The chapter also introduces the new technology called Fortenza Duo that was developed by Syngenta to help minimize the devastating effect of FAW pest. The problem underlying the study is clearly stated as well as the underpinning research objectives and questions. Chapter one also outlines the research hypotheses and explains the significance and scope of the study.

FAW, (*Spodoptera frugiperda* J.E. Smith) is a *lepidopteran polyphagous* pest native to tropical and subtropical America, and is one of the most important pests of maize in Central America (Andrews, 1980) and Brazil (De Almeida et al., 2002). It belongs to the genus *Spodoptera*, known as armyworms, the most destructive group of *Noctuidae* in terms of monetary loss to agriculture worldwide (IITA, 2016). The pest appeared suddenly in Africa in early 2016, when it was first reported in Central and Western Africa (Goergen, Kumar, et al., 2016) from where it spread very quickly. The pest was first reported from the West African countries; Togo, Nigeria, and Benin (IITA, 2016; IPPC). As of May 2017, the pest was reported in 11 Southern African countries and 14 East and Central African countries. By July 2017, the pest was in all SADC countries except the Island states and Lesotho. By the end of 2017, it was found in most of sub-Saharan Africa (Day et al., 2017), threatening food security (Devi, 2018). Some of the factors helping FAW to spread quickly over the continent are its propensity to attack a wide range of crops (Huesing, Prasanna, et al., 2018), capability of producing many eggs (Sparks, 1979), its preference for maize (Devi, 2018) and its ability to migrate over long distances (Rose, Silversides, et al., 2012). The pest has a preference for *Poaceae* or *Gramineae* family such as Maize, Wheat and Sorghum; however, the pest has a wide range of different hosts more than 80 plant species that include sugarcane, cotton, soybean and potato; including ornamental plants, fruit trees and weeds. A report commissioned by the Department for International Development (DfID) and compiled by CABI indicated that arrival of FAW in Africa has the potential to cause maize yield losses from 8.3 to 20.6 million tonnes per annum (21-53% of production), valued at US\$ 2.4 - 6.2 billion, if left uncontrolled (Abrahams, Bateman, et al., 2017, Day, Abrahams, et al., 2017).

As FAW is a new and urgent pest to Africa, both the public and private sector are trying to act quickly to develop guidelines and control methods. Several organizations including the Food and Agriculture Organization and the International Maize and Wheat Improvement Centre published reviews (FAO, 2017, FAO, 2018, Prasanna, Huesing, et al., 2018). The private sector has brought chemical and biological control methods to the market, and both private and public sector are developing host resistant varieties. Syngenta has developed an insecticide called Fortenza duo which is a seed coating technology for controlling FAW in the early stages of maize plant. During the 2018-2019 season, the company was conducting proof of concept trials and setting demonstration plots on Fortenza duo in Zambia. This study aimed at evaluating farmers' appreciation of the technology as well as the effectiveness of the use of Fortenza Duo in controlling fall army worm in maize in Zambia.

1.2 Background to the Study

The FORTENZA® product family contains cyantraniliprole* a Group 28 insecticide, belonging to the diamide class of insecticides. Applied as a seed treatment, FORTENZA® Duo is quickly taken up by the roots and moves upward in the plant through the xylem system, controlling a broad range of above ground insects. The product is also distributed into the soil around the root zone forming a bulb of protection against below ground insects. It is a soil systemic product. Insects are controlled mainly by ingestion but some contact activity can also be observed. FORTENZA® Duo provides excellent crop protection resulting from a rapid feeding inhibition and long lasting residual effect. The product was launched in 2014 and is available in many countries worldwide (Trocza et al., 2017). During the 2018-2019 season, Syngenta Company working in partnership with Conservation Farming Unit (CFU) and CFU identified farmers, and the ministry of agriculture extension workers planted several trials and demonstration plots in the Copperbelt, Central and Eastern provinces of Zambia. Syngenta Company also worked with Zambia Agriculture Research Institute (ZARI) and set up a trial at Mount Makulu research station in Chilanga to evaluate the efficacy of fortenza duo technology.

This study used the set up trials and plots on farmer's fields to evaluate fortenza duo technology. When evaluating a new agricultural technology, it is important to understand farmers'

preferences and evaluate how the new technology fits. One way is to invite farmers to the trials, ask them which criteria or traits they value and how important they are (De Groote and Siambi, 2005, De Groote, Siambi, et al., 2002). This method of inviting farmers to evaluate new maize varieties has been used extensively in East Africa (De Groote 2014). On-farm trials are used and are found to be effective in evaluating a new technology like the use of FORTENZA® duo in the control of fall army worms (FAW).

1.3 Problem Statement

In Zambia, crop productivity is low. The arrival of FAW in Zambia has made the situation worse for the farmers, as it has increased costs for the farmers through pesticides purchases as well as increased labour demand by frequent spraying of the pest. If not controlled, the FAW can wipe out the entire field of crops leading to total loss. However, Syngenta developed an insecticide called Fortenza duo, a seed coating insecticide which according to the company can protect crops from FAW attack in the first one month. The insecticide has many traits and it can control about 28 crop pests (Trocza et al., 2017). If the efficacy of fortenza duo is proven on-farm, it can help reduce farmers' financial costs and labour demand. However, the efficacy of Fortenza on farmers' crop fields has not been evaluated in Zambia. Moreover farmer preferences towards such a new technology may provide useful information on its adoptability potential. Generally, before rolling out and encouraging the farmers to adopt this technology in the country, it's important to carry out farmer evaluation of fortenza duo technology to evaluate its effectiveness, and that was the focus of this study.

1.4 Research Objectives

1. To assess farmers' preference for Fortenza duo treated maize versus untreated maize varieties (hybrid and local varieties).
2. To determine farmer demographic characteristics influencing FAW severity Scores.

3. To evaluate the effectiveness of Fortenza duo technology in controlling FAW in maize fields in Zambia.

1.5 Research Questions

1. Do farmers prefer Fortenza duo treated maize as compared to non-Fortenza treated maize varieties (hybrid and local varieties)?
2. What are the farmer demographic characteristics influencing FAW severity Scores?
3. Is the Fortenza duo technology effective in controlling FAW in maize fields in Zambia?

1.6 Significance of the Study

This study is of great importance to the Zambian farmers, the chemical company (Syngenta), and the nation at large, and other African farmers with similar maize production systems. The study has necessary information on the suitability of the Fortenza duo technology to the farmers. It also highlights the criteria in the maize treated with Fortenza duo that are preferred by the farmers. The study also captured information on the effectiveness of this technology. This provides relevant information to the farmers and the chemical company (Syngenta) on the expected adoption and use of Fortenza duo in controlling FAWs. Evaluating the effectiveness, suitability and preference for Fortenza duo technology helps the Ministry of Agriculture to plan for adoption of new technology. Once the technology is adopted and used by farmers, it will reduce farmers' costs, labour demand by frequent spraying in controlling army worms and will contribute to increased yield for food security, poverty reduction and economic development; and this will benefit the country by providing citizens with access to cheaper food. This research study also makes contribution to the body of knowledge concerning crop protection and evaluation of technologies in agriculture.

1.7 Scope of the Study

This study focused on evaluating the use of Fortenza duo technology in controlling FAWs. Farmers evaluated the technology in terms of suitability, preference and effectiveness in controlling army worms. Farmers evaluated the use of Fortenza duo technology in controlling FAW in maize. Six sites were visited for the farmer evaluation of the demonstration plots. The study also carried out a survey of farmers who planted Fortenza duo treated maize and other non-treated hybrid and local varieties to obtain information on the effectiveness of the technology. The study also included a control group of farmers who did not plant Fortenza treated maize. The study was conducted in Copperbelt, Central and Eastern provinces, with an additional evaluation of a trial in Chilanga at Mount Makulu Research Station.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

In chapter two, literatures related to evaluation of technologies in agriculture is given. This includes the preference for the new technology, suitability and effectiveness of the technology, and also factors considered important by farmers in selecting and adopting a technology. In this chapter, a brief review on pest management is discussed, then theories surrounding the evaluation and use of technologies in agriculture are explained. Further, the conceptual framework anchoring this study is explained, and several empirical studies of different researchers that are in line with the study are discussed.

2.2 Theoretical Review

The concept of participatory research is based on the premise that if small farmers do not perceive the relevance of a technology, they will not adopt it. The aim of participatory research is to transfer initiative and decision-making power to farmers who, in the end, provide a detailed and practical experience and knowledge of their production system that is useful in technology improvement. Participatory research helps to provide indigenous knowledge that exists in the community and combines it with the ideas and knowledge of other stakeholders for technology advancement. Therefore, farmer evaluation of new technology like Fortenza duo in controlling FAWs is essential for the success of any agricultural technology. Agricultural projects have to ensure that farmers participate in planning, implementation and evaluation of new technologies (FAO, 2006).

2.2.1 Theory of Planned Behaviour

The theory of planned behavior (TPB) originated from social psychology. According to this theory, an individual's intention to perform a certain behavior is a key factor for behavior. The theory assumes that intentions capture motivational factors that influence behavior and depend on the beliefs that link behavior given certain results and the perceived social pressure to perform

an action (Kautonen et al., 2013). Intentions are expected to influence behavioral performance to an extent that an individual has real control over behavior. In the agricultural environmental context, planned behaviour theory contributes to understanding the expected farmers' behaviors and any observable action, which has significant implications on the adoption of technologies in agriculture (Kautonen et al., 2013). The theory of planned behaviour is an appropriate theoretical framework that provides a model for understanding farmers' beliefs and motivations and how information can influence behavior (Fielding et al, 2008). Farmers' individual attitudes, social pressure and performance of the technology should be assessed to understand what encourages farmers to accept or reject an agricultural technology. It is therefore important that there's evaluation of the Fortenza duo technology to ensure that it conforms to the farmers social setting and can perform to the farmers' expectation. This will help towards learning the adoption potential of the technology quickly.

2.2.2 Diffusion of Innovation Theory

One important theory to this study is the theory of diffusion of innovation. The diffusion of innovation theory provides an adequate explanation of the relationship between technological innovations and the social relations. According to Rogers (2003), diffusion is the process by which an innovation is transmitted through certain channels over time among the members of a social system. An innovation spreads within a social system through its adoption by individuals and groups.

In agriculture, the diffusion of any agricultural technologies, e.g., mechanization, improvement of seeds, pest management like the use of Fortenza duo in controlling army worms helps to increase productivity. This helps to increase yield and improve the standard of living of the farmers. As stated by Rodgers (2003), there are four main elements of diffusion of innovation which are; innovation, time, social system and communication channels. To this study, innovation and social system elements are the most important. Diffusion of innovation will only occur if there is a new idea or practice or technology like Fortenza duo, which has been accepted by an individual or a group of people. An innovation therefore is a practice or an object that is perceived as new by an individual or an improvement compared to that existing by the members of a social system. Therefore, in the evaluation of Fortenza duo, it's important to ask whether

this technology is an improvement to the existing control measures for army worms, and if it is more effective.

In the use of an innovation (e.g. use of Fortenza duo technology), it is important to ask questions that ensures that the new technology meets the characteristics of an innovation (Rogers, 1962). It is important to ask whether the use of new technology (Fortenza duo) gives a relative advantage; that is, a relationship between the expected benefits and the costs of adopting this innovation. This means asking if the technology offers economic profitability, lowers the costs, reduces the discomfort, gives social prestige, helps saving time and the efforts, and gives better reward (yield or profit). The new technology (Fortenza duo) has to be assessed also in terms of compatibility; which is the degree to which an innovation is consistent with the farmers past experiences and their needs. The other characteristic of an innovation is to assess its complexity; that is, the degree to which the technology is difficult to understand and use. The other element of an innovation is its trialability (Peshin, Vasanthakumar and Kalra, 2009); that is; the degree to which it is possible to experience an innovation both in a limited resources and in terms of the given time. The last element of an innovation is to ensure its observability, that is; the degree to which the results of an innovation can be made visible to others. When there's greater observability and communicability of the results, there will be higher adoption rate. The other important element in the diffusion of innovation theory is the social system, in which it is important to ensure that the new technology (Fortenza duo) conforms to the social system that exists in a particular area. This requires asking questions whether using Fortenza duo is in line or acceptable by the social system. The diffusion of Fortenza duo technology at the village will depend on the structural characteristics of the social system or the village, and may be heterogeneous or homogeneous. In a homogeneous village, population maybe similar in demographic or social characteristics like culture or religion; while in a heterogeneous village the population may vary in characteristics (Peshin, Vasanthakumar and Kalra, 2009).

According to De Janvry, Macours and Sadoulet (2016), the diffusion of a new agricultural technology like Fortenza duo will require that farmers know the existing benefits of the technology. Farmers want to know the expected benefit or return before deciding to adopt a technology. Sadoulet (2016) indicated that a more realistic view of the world of heterogeneity in agricultural production suggests that what farmers should learn is a more complex multivariate

relationship between the input and the output in terms of the expected yield and earnings. It is therefore important to assess the Fortenza duo technology in terms what farmers can value as the benefit or observed return of using this technology in controlling army worms.

2.2.3 Theory of Revealed Preference

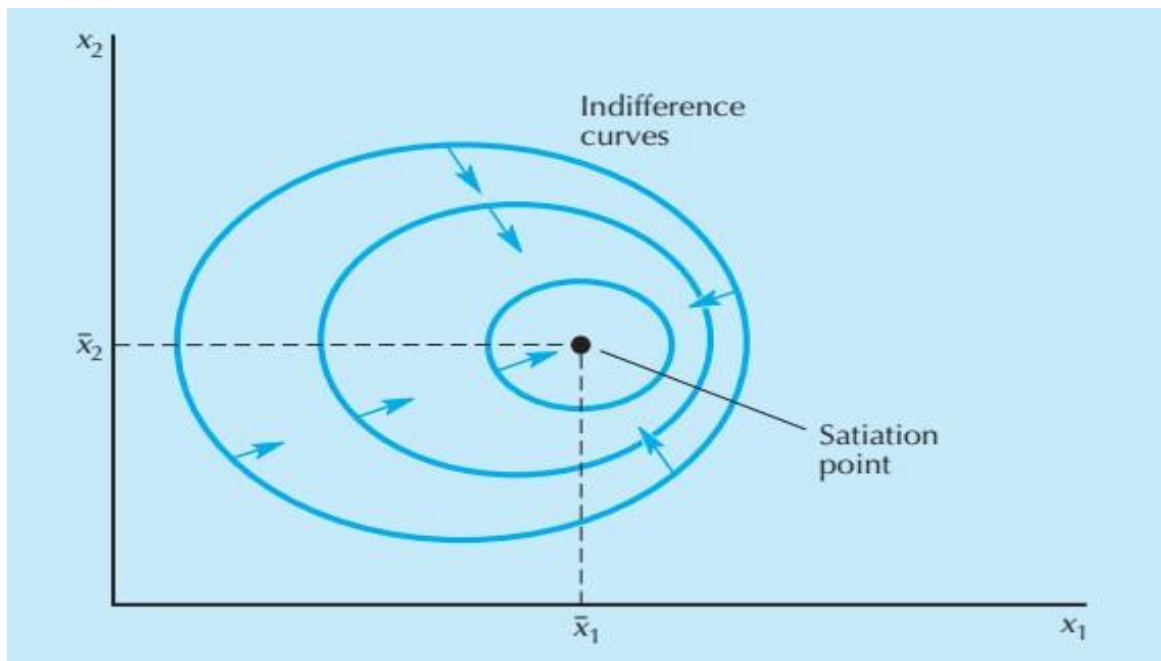
According to the theory of revealed preference (developed by Samuelson Paul and John Hicks), a consumer's indifference curves can be derived from the observation of the real behavior of the consumer market and without the need to directly ask for preferences. If a consumer purchases basket A instead of basket B, although A is not cheaper than B, we can deduce that the consumer prefers A to B. The theory of revealed preference is based on the assumption that: The consumer has a taste, and they do not change during the period of analysis; Consumers' tastes are consistent, so that if the consumer buys the A basket instead of the B-basket, the consumer will never prefer B to A. Consumer tastes are transitive, so if the consumer prefers A to B and From B to C, then the consumer will prefer basket A to C; and the consumer can be induced to buy any basket of commodities if their price is sufficiently small (Salvatore, 2008). From this theory, it is important to ask whether the use of Fortenza duo technology offer farmers with a sufficient small price compared to the existing control measures for army worms. This could be in terms of reduced costs, reduced labour or increased yield. This can help to evaluate whether the Fortenza duo can be preferred to the existing measures.

2.2.4 Choice Theory

According to choice theory people make choices in everyday life with respect to the alternatives available. Therefore, rational choice is a process of choosing the preferred option from the available alternatives. An individual will choose a particular good or technology or service depending on his or her criterion or traits that they consider to be important to them (Jonathan and Paul, 2004). The rational choice theory is a model of optimization. One of the assumption of choice theory that is important in this study is that consumers are non-satiated. This assumption states that given two bundles of goods 'A' and 'B', a consumer will choose bundle 'A' if it contains at least more of one good and no less of the other goods in that bundle. This theory can

explain why farmers may choose adoption of Fortenza duo. If Fortenza duo contains more traits (e.g control against many pests, more effective, less risky, easy to use, less labour demand) than the use of other army worm control measures, then farmers will prefer use of Fortenza duo to control for army worms. The assumption of non-satiation can be represented in a figure as shown below.

Figure 2.2.1 Non-satiation Assumption in Choice Theory



Source: Varian, 2010.

From the assumption of non-satiation in the above figure, if the fortenza duo technology contains more of the traits 'X₁' and 'X₂' than the alternative control measures, then it will be preferred to the alternatives. If the Fortenza duo is preferred to the alternatives, then it lies above the satiation point.

2.3 Empirical Review

This section brings out some of the study findings that have been conducted by other researchers concerning evaluation of new technology. Some of the studies in this section involved evaluation of seed coating technologies in controlling pests and weeds in the fields. The section also brings

out studies on evaluation of new crop varieties for possible adoption by farmers. The studies presented in this section were done by researchers in other countries.

2.3.1 Adoption of Agricultural Technologies

According to Goodell (1984), the farmers in the third world would not adopt integrated pest management easily if the technology is too demanding. The technology is less attractive because it is labour intensive causing payment of high wages. In this study therefore, it is important to evaluate the use of Fortenza duo as to whether the technology reduces labour demand for easy adoption.

According to the Lancaster model on choice of consumers; consumers derive the satisfaction from the attributes of a good and not a good itself. In the same vain, farmers obtain utility from the attributes of a new technology that it offers. This could be new crop varieties, new farming system or new technology like the use of Fortenza duo technology (De Groote, 2017). It is therefore important to evaluate which attributes farmers' value in maize, and secondly if the attributes of the Fortenza duo technology respond to those that satisfy the farmers.

For a new technology, it is important to evaluate and test the technology to determine how easy the technology is to use and its durability. It is also important to establish whether the technology is viable and what effect it has on households (FAO, 2006). Fortenza duo technology should be evaluated to establish its durability and how easy the technology is to use by farmers. The Fortenza duo technology should also be assessed to establish whether it is effective in preventing crops from army worm attack.

In a new technology, costs should be assessed, e.g. labour cost, spraying, costs of inputs, and yield should also be assessed. This helps to determine whether the use of the new technology (Fortenza duo) offers farmers a comparative advantage, if compared to using the already existing technologies.

Yield is important to farmers, and the new technology (Fortenza duo) has to be evaluated on whether it increases crop yield or not. The other concern should be the environmental risk of using a technology. This may involve calculating the chronic and acute risks of using a particular pesticide like Fortenza duo (Jaka et al., 2015).

It is also important to evaluate the new technology in terms of its ability to control pests in the field, and also the side effects of using a particular technology, i.e., assessing the harm that the technology may have on humans, animals, plants and the environment. The costs of using a particular technology also needs to be assessed, including the costs of reducing the use of a particular technology. Important also to note that pesticides may have externalities which are neglected when factoring in costs (Pretty and Bharucha, 2015). For farmers to invest in pest reduction technologies, they consider infestation level in the field, the loss in crop that can be incurred, technology cost and effectiveness of the technology (De Groote, 2008).

2.3.2 Evaluation of the Effectiveness of Technologies

When testing the performance of Imidazolinone-Resistant (IR) maize for increased yield and striga control, De Groote et al. (2008) compared it to the conventional maize produced during several trials on farms in Kenya. In the first series of the studies, researchers compared two hybrids of IR corn with two conventional varieties on 78 farms distributed in four districts during the prolonged rains in the year 2002. The average yield of IR maize was twice the average yield of 1.7 tons/ha and was at 3.4 tons/ha. At 12 weeks, the mean number of Striga plants that emerged in the four plots was used as an indicator of Striga infestation. The study distinguished three levels of Striga infestation: high (> 50 plants/m²), medium (10-50 plants/m²) and low (< 10 plants/m²). The study results showed the effect of Striga on maize yield. The commercial control had a slight increase compared to the local control at the low level of Striga, of 2.5 tons / ha. The local control method was less sensitive; the yield reduced only a quarter below the low Striga level, but it was half below the high infestation level. The study found that the IR maize hybrids did not suffer any loss of yield under the medium Striga infestation; and the yield only reduced by 20% under high level of infestation. Due to the difference in management between researchers and farmers; a second test was carried out under farmers' management in 60 farms (De Groote et al., 2008). The study found that yield of IR corn was twice the yield in the control, 0.69 tons per hectare increase. Therefore, evaluating the Fortenza duo technology in terms of how it affects yield is significant for determining the effectiveness and value of the technology.

A study by Ramamurthy et al (2005) on evaluation of the seed-priming technology in sorghum used farmers to evaluate the technology. The farmers submerged the seeds for specific period of time of about 10 hours, then dried the seeds and sowed. The study used a simple experimental design. Split-plot-design was used for data analysis, soil was taken in the main plot, for varieties it was taken from the sub plot, and the priming was taken from the sub-sub plot. In evaluating this experiment, farmers took a farm walk and answered questions from a focus group discussion, and the last exercise was the matrix ranking. The use of ranks or scale is also applied to this current study for farmers to evaluate the use of Fortenza duo in controlling FAWs.

Ramamurthy et al (2005) found that priming seed at the farm improved the average sorghum yield by about 10.2% in 2001 and 2002 and the increase was significant in the two years. Despite that, the effect of priming seed on improving grain yield was not observed in the year 2003. This was attributed to good rainfall distribution which reduced the beneficial effect seed priming to aid with germination and plant establishment.

Mostafa and Thormann (2014) conducted a study in which they evaluated low pressure drip irrigation system for small scale farmers. The objective was to evaluate the performance of a low pressure drip system (LPS) for three years, then calculate the time of consumption and the costs of maintenance and lateral recovery before the harvest, and lastly determine the benefits and problems with the drip irrigation system. The study found that the old drip line was causing reduction in the uniformity of the distribution and an increase in costs. One important lesson from this study is ensure that the new technology (Fortenza duo) needs to be more effective in controlling army worms and/or in reducing the cost of controlling fall army worms.

Bucheyeki et al., (2008) conducted on-farm and on-station trials in Tanzania, Sikonge area, beginning 2003 - 2006. The study used randomized complete block design (RCBD), having five plots in each of the replications. Five varieties of groundnuts were planted in an area of 25m² with a spacing of 0.9 x 0.15m. The net area for the three ridges that was harvested is 15m². Using analysis of variance (ANOVA), the study found that the new varieties had a significant increase in yield. Similarly, in this study it is important to evaluate the significance of using Fortenza duo on crop yield, and this can also be compared to other control measures in terms of yield.

In a study by De Groot et al. (2010: 103); participatory rural appraisals (PRAs) were conducted in selected communities to initiate conversations with farmers. The objective was to discuss whether the technologies fits well with farmers. The farmers classified and listed the criteria they would use to evaluate different treatments. Farmers evaluated the trials with respect to striga resistance, improved soil fertility, yield and labor savings as criteria for evaluating different treatments. Farmers provided a general assessment score for each of the treatments. Similarly, in this study farmers will be asked to score the performance of Fortenza duo in controlling FAW, in ensuring good crop yield, and other criteria farmers find important.

In another study by De Groot et al. (2010: 41) on the effect of different technologies on the incidence of pests, the study indicates that the push-pull system had significantly reduced the damage of maize by stalk borer. It is therefore important to evaluate the effectiveness of Fortenza in preventing crops from been attacked by the army worms.

Mignouna et al. (2011) conducted a study on the adoption of imazapir-resistant maize technology for controlling Striga in Kenya. In this study, the Striga weed was one of the main obstacles to cereal production in Western Kenya. However, a new technology ‘imazapir-resistant maize was developed to control Striga infestation in the fields. Despite the effectiveness of this technology, the adoption was low at 25%. Among the factors affecting adoption of technology was lack of information, costs of purchasing inputs, the traditional control method was also indicated to be better by the farmers and the new technology was indicated to be too risky for adoption. Similarly, evaluating the new technology Fortenza Duo in controlling fall army worm is important to ensure that the technology is well assessed for adoption. Therefore, evaluating the Fortenza duo technology in light of farmers having information about it, how risky the technology is to adopt and also comparing it to other existing control practices is significant for pre-determining the success of the technology in controlling fall army worms in Zambia and Africa at large. Mignouna et al., (2011) study found that the benefits of imazapir-resistant maize were increased yield, increased household income and reduced poverty. Fortenza duo should also be assessed in terms of benefits and its effect on crop yield. However, adopting the imazapir-resistant maize technology required different stakeholders to encourage farmers to adopt the

technology. Farmers were not yet well equipped to innovate, and this could have prevented their interest.

A study by Bucheyeki and Tueli (2013) evaluated bean varieties for adaptation and adoption in Tanzania, Kigoma region. The objectives of the study were to evaluate bean varieties for yield under farmers' management and to evaluate farmers' preferences on bean varieties. This current study will also assess farmers' preferences for the new technology (Fortenza duo) in controlling fall army worms and compare it with other existing control measures. In a study by De Groote et al. (2002), farmers evaluated the different test varieties with respect to their own criteria. The evaluations of farmers were combined to select the varieties to be tested on the farm. Farmers evaluated the varieties twice, at tasseling and harvest time. Pests are the most restricting factor in maize production as was indicated by the farmers. Weevils were indicated the most important pest that attack maize, followed by stem borers and termites. At the time of that study, fall army worm had not yet arrived in Africa, but currently it is now a dangerous pest to crops in Africa.

In an empirical study by Sabur and Molla (2001); almost all farmers express their opinion that the application of pesticides contaminates water, and 86% believed that the application of pesticides is harmful to agricultural workers. More than three quarters say that the use of pesticides could contaminate the air. The application of pesticides is harmful to the health of other people and animals, as was expressed by more than half of the respondents. Finally, 41% indicated that the crop could be contaminated after using pesticides. With respect to water pollution and agricultural workers, most farmers believe that the effect of pesticide application is more serious than other effects. However, 90% of farmers still believed that there is a positive relationship between the use of pesticides and agricultural production, as production will be higher if they use more pesticides. According to this study; 87% of respondents believe that the application of pesticides is profitable. A large part of the big farmers was convinced of the profitability of the use of pesticides. From this study, one important lesson is evaluating the new technology (Fortenza duo) in terms of how risk and harmful this technology is to be used by the farmers.

According to a study by GAST (2014); using Bordeaux mixed with sulfur was effective in managing crop diseases in the United States, and this led to widespread adoption leading to

reduced crop losses. Controlling for late blight in potatoes increased yield to 64% through using Bordeaux mix (Jones, Giddings and Lutman, 1912). The use of Bordeaux mix also helped to decrease cranberry rot by about 50%. Application of Sulfur to peaches in Georgia reduced brown rot losses by 13%. Therefore, fungicides have been used in production of fruits and vegetables to control one or more plant diseases since the 1900s.

In a study by Girma (2005) on the selection of maize varieties tolerant to drought, the farmers were interested in certain parameters such as yield, earliness and general appearance like vigor of the varieties. Ten varieties were considered better or comparable to the standard control. In general, farmers responded positively to the new varieties they evaluated. In the first phase, farmers' assessment indicated that there was a need for adaptation with the researchers, basing on grain yield and other agronomic parameters. The results also show that farmers are eager to participate in the selection of new varieties, but their selection is very different from that of breeders. Therefore, it is important to carry out farmer evaluation on the Fortenza duo technology as a tool for controlling FAWs. It is also important to evaluate how use of Fortenza duo impact on crop yield, as indicated many studies highlighted above.

2.3.3 Farmer Characteristics that may Influence Evaluation Outcome

Farmer characteristics are often considered important in adoption of pest control measures and influence management outcome of pests. Among the farmer characteristics important in influencing pest management outcomes is age, education and household size. Age is typically found to be negatively correlated with adoption (Adesina and Zinnah, 1993). This relationship is explained by the assumption that as farmers grow older, there is an increase in risk aversion and a decreased interest in long-term investment in the farm. Younger farmers are typically less risk-averse and are more willing to try new technologies. This will therefore influence management of crops and the outcome of crop management. Formal education increases the farmers' ability to understand and respond to information concerning new technologies (Caviglia-Harris, 2003). Education increases the ability to think analytically, make practical adoption decisions, and use a technology appropriately. Studies show that farmers with more formal education tend to adopt more agricultural technologies (Chaves and Riley, 2001; Caviglia-Harris, 2003). Household size is another consideration of adoption. Larger households adopt new technologies more often than

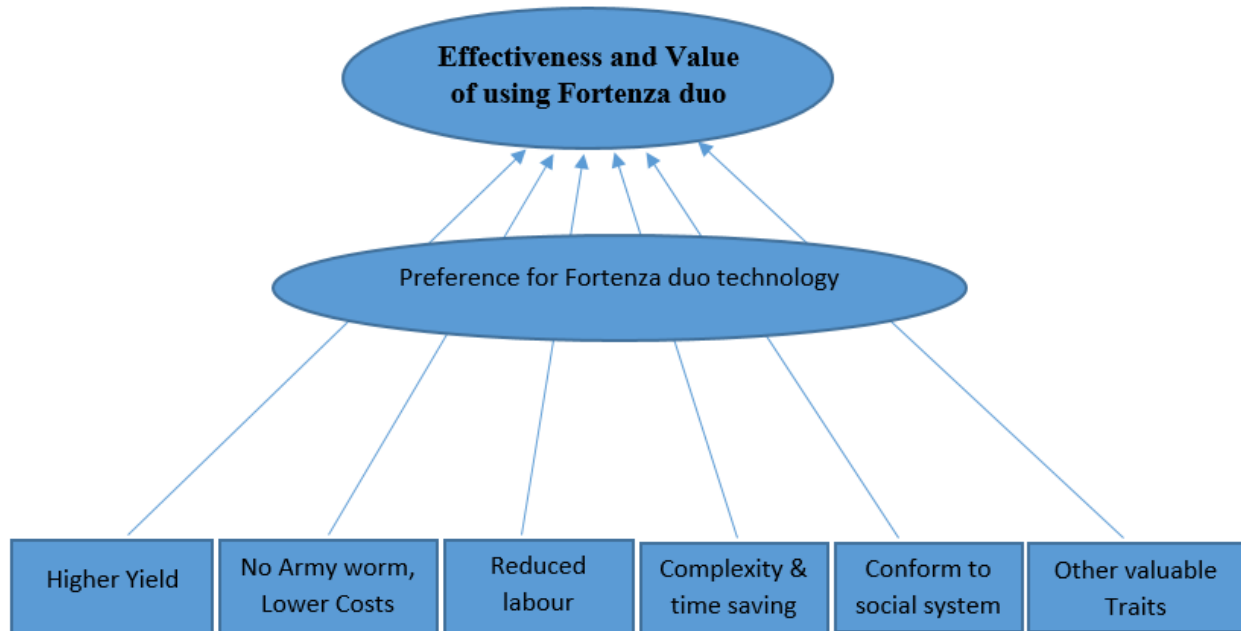
smaller households, holding other factors constant (De Souza et al., 1999). Households containing members able to participate in on-farm activities enable farmers to adopt labor-intensive technologies, resulting in better management of crops. Income may also discourage or prevent adoption. Populations with higher incomes exhibit a willingness to accept more risk and adopt complex technologies. Farmers with larger farms invest more in pest control leading to better management (Orr, 2003). These farmer characteristics will directly affect management of crops in terms of controlling for pests like fall armyworm resulting in either high or low infestation.

A study by Musemwa (2013) found that age of household head, excellent production knowledge and level of specialization affected technical efficiency of the farmers. Allocative efficiency was only affected by good production knowledge, farm size, arable land owned and area under cultivation. Factors which affected economic efficiency of the farmers were secondary education, household size, farm size, cultivated area and arable land owned. These factors may also play a key role in crop management like control of fall armyworm, resulting in low infestation or high infestation.

Among the factors affecting agricultural production Bihon (2015) found that landholding size, possession of oxen, village distance to the district market, and average distance of plots from the homestead are significant factors. In an empirical study, Chomba (2016) found that the socioeconomic characteristics of the farmers that were found to be influencing adoption decision of the technology were level of formal education, gender and off-farm income. Age of the farmer, farm size and contact with technology promoters did not affect their adoption decision. Alassaf et al. (2011) found that socio-economic and land resource profile of farm family had important effect on farmers' decision to continue farm activity. The profiles included factors of: age and education level of household head, farm income and family labour work at farmer, these socio-economic factors significantly influenced the farmer's decision to continue farming. These factors may also influence management of pests like fall armyworm by farmers. It's important to evaluate the influence of these farmer characteristics on the outcome of new technologies, like how farmer characteristics may influence the scores of FAW infestation under the new technology of controlling FAW such as Fortenza duo.

2.4 Conceptual Review

Figure 2.4.1 Conceptual Framework of the study



Source: Author, 2020.

From the conceptual framework in figure 2.3.1; the contribution and performance of Fortenza duo in terms of protecting crops from army worm attack, lower costs of FAW control, reduced labour demand from pesticide spraying and planting (which is carried out in one operation), time saving and easy of using the technology, conforming to the social system of the communities in which farmers operate, contributing to higher yields and other valuable traits of the technology will ensure preference of the technology to the already existing control measures, and this will impact on the effectiveness and value of the Fortenza duo technology in controlling FAW.

2.5 Conclusion on Literature Review

The theoretical review pointed to many factors that makes a technology suitable for adoption by farmers. These include contribution of the technology to yield, reducing pest attack, lowering

farming costs, decreasing labour demand, ease of use, lower risk and conformity to the social system. The other sections in the literature has also presented some of the factors in evaluating the effectiveness of a new technology. The chapter also reviewed some of the studies and their findings, including the methods that were employed in carrying out the studies. However, there is limitation in the literature in terms of farmer evaluation of technologies; there are so many agricultural chemicals; pesticides, fungicides and herbicides; however, farmer evaluation of these chemicals in terms of preference by farmers, contribution to yield and effectiveness is limited. The study also reviewed some studies on farmer characteristics that may influence outcome of technologies. Therefore, more farmer evaluation studies should be encouraged for pre-determining farmer adoption of new technologies.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

Chapter three presents the research methodology that was used in achieving the research objectives. The research methodology includes; research design, research approach, target area, sample size and sampling techniques, data collection tools and data quality control (validity and reliability).

3.2 Research Design

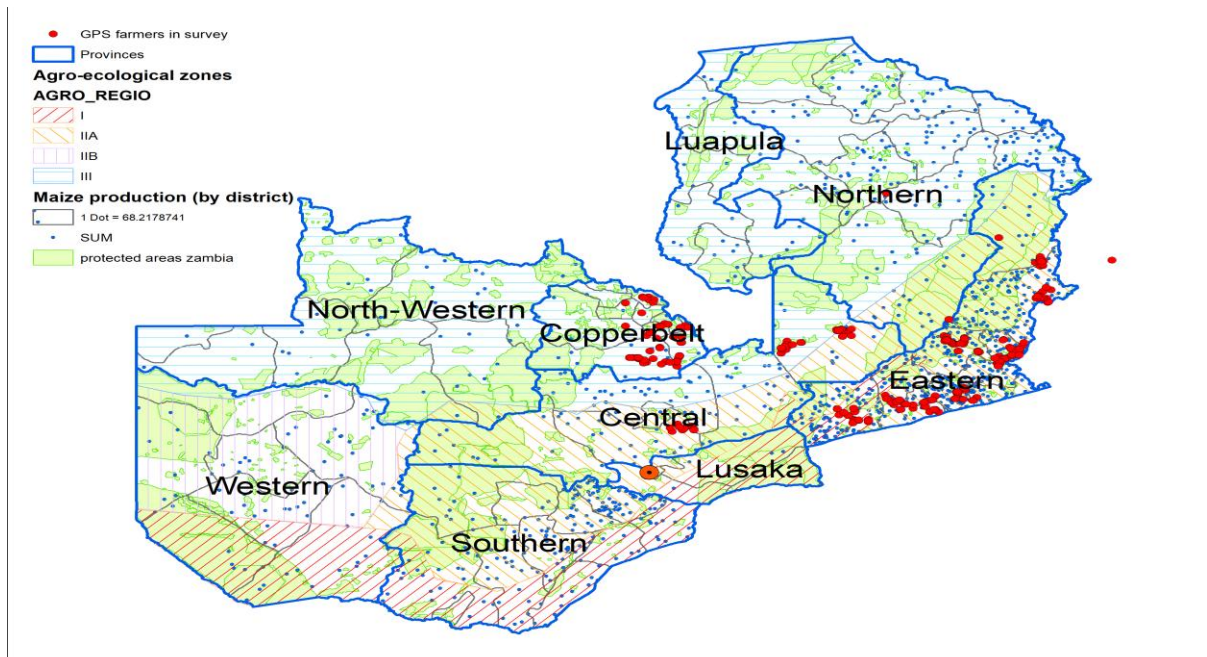
In evaluating the efficacy of fortanza duo technology in controlling for fall army worms in Zambia, a participant/participatory survey in which farmers were invited to the maize demonstration plots in six different sites covering four districts of the country (Serenje, Mpika, Mpongwe and Masaiti) was conducted. The choice of the districts and the sites was based on availability of the demo plots during the time the study commenced. This survey had a total of 202 participants; Serenje district had 68 participants, Mpika district had 14, Masaiti District had 77 and Mpongwe district had 43 participants.

Farmer evaluation was also conducted during the mid-season for the on-station winter maize trial established at the Zambia Agricultural Research Institute (ZARI), Mt Makulu research station, with 12 farmers. The trial had eight treatments; the untreated maize seeds was planted in 4 plots, 3 plots were treated each with one pesticide, either Looper kill or denim fit or Nimbecidine. Fortanza treated maize seeds was planted in 4 plots, 3 plots were each treated again with one pesticide, either Looper kill or denim fit or Nimbecidine. The combination of the two factors (treated and untreated seeds) led to eight different treatments, which were repeated twice for a total of 16 plots, randomly assigned. The trial at Mount Makulu research station was again evaluated at harvest (end-season evaluation) with 32 farmers.

In determining the efficacy of fortanza duo, a farmer survey was also conducted, in which farmers who planted maize treated with fortanza duo (treatment farmers) were surveyed and interviewed on their experience with the technology and fall army worms. For comparison

purpose, the study also interviewed farmers who did not plant fortenza treated maize (called control farmers), and these were farmers who are located within the same areas with the treatment farmers. A total of 315 respondents were randomly selected based on the probability proportional to size sampling criteria at provincial level (153 treatment farmers and 162 control farmers). The sampling frame was the list of farmers with trials set up by Syngenta and its partners in thirteen districts visited for the study. The farmer survey covered three provinces of the country, which are Copperbelt, Central and Eastern provinces from which the thirteen districts were selected. Figure 1 below show the points where farmers were surveyed for the study. In the Zambian map shown in figure 1, the red dots indicate the location for the farmers that participated in the survey. A random sub sample of 35 farmers taken from the 153 treatment farmers was studied in detail to validate information on their experience with FAW, the harvest gotten and the preference for the technology. Additional questions were added in which farmers were asked to score the likeness of each maize criteria for Fortenza treated maize and the non-treated hybrid and local maize varieties. From the sub sample of 35 farmers, the study had 177 observations (68 fortenza treated maize fields, and 109 non treated maize fields).

Figure 3.1. Map with farmers surveyed



3.3 Tools Development

The study questionnaires were designed based on the objectives of the study and on the information from various literatures on how a new technology can be evaluated. In developing the questionnaires, the study used the template developed for evaluating seed technologies by CIMMYT in Kenya, which helped to provide guidance in setting up research questions.

3.3.1 Pretesting of the Questionnaires

The pretesting of the evaluation questionnaire was done at Mount Makulu Agriculture Research Station in Chilanga. The total number of farmers interviewed was 10 and they came from the nearby villages surrounding Mt Makulu. The pretesting was witnessed by staff from Syngenta, staff at Mount Makulu Research station, staff from CIMMYT and four representatives from the University of Zambia. After pretesting, the researchers removed some questions deemed not important, and added two more questions to the questionnaire. A similar questionnaire was used for evaluating the winter maize trial at Mount Makulu ZARI station and the farmer evaluation of the rain-fed demonstration plots in six sites of the four districts in Zambia.

The farmer survey questionnaire (also called economic analysis questionnaire) which included questions on efficacy of Fortenza duo was not pre-tested, but was thoroughly vetted among the survey team members including the consultant.

3.4 Data Collection

The study used questionnaires to collect primary data from the farmers who were invited to observe and evaluate the maize whose seeds were treated with Fortenza duo technology. Farmers were asked to provide the criteria they find important in selecting maize varieties (yield, grain size, cob size, resistance to fall army worm, etc.). The farmers evaluated the maize plots using the criteria they consider important in maize. Invited farmers used a 5-point Likert scale to score their likeness of the various maize criteria: A = like very much, B = like, C = neither like nor dislike, D = dislike, E = dislike very much, to show how much they like the maize in the plots. For the survey conducted at Mount Makulu, 12 farmers participated in the evaluation at mid

stage of the trial, and 35 farmers participated in the harvest stage evaluation of the maize trial. The farmer evaluation survey for the rain-fed trials had 202 farmer participants and the data was collected at the harvest stage of the maize crop.

A farmer survey was conducted to determine the effectiveness of the technology in controlling for fall army worms. The survey interviewed 153 treatment farmers and 162 control farmers. Farmers were asked to indicate whether they experienced FAW in their maize fields or not, and at what stage in weeks was FAW first observed in their fields. Farmers also indicated the severity of FAW attack (0 = very low infestation, 1 = low infestation, 2 = high infestation, 3 very high infestation). The five point Likert scale used in farmer evaluations was also used in farmer survey for the farmers to score their likeness of the various maize criteria.

3.5 Data analysis

Data were analyzed using Stata software. Descriptive statistics such as frequencies, means and standard deviations for the relevant variables were estimated and analyzed in order to glean the key findings of this study. For more robust analysis, ordinal and mixed regression models were part of the study's empirical strategy. The use of ordinal regression analysis was adopted from previous studies that evaluated the use of different technologies in agriculture and other disciplines (Coe, 2002; De Groote *et al.*, 2010). The ordinal regression model is equivalent to the proportional odds model. Mixed regression was used to evaluate whether there were any statistical significance differences between the FD treated maize and the un-treated maize in terms of the time when FAW attacked the maize fields (Pinheiro and Bates, 2009).

To analyze farmers' overall evaluation of the on-station trial at mid-season and end-season, farmers' self-ratings of the treatments was used for overall evaluation and resistance to fall army worm as the Fortenza efficacy outcomes. Since the scores or ratings used in the farmers' evaluations are ordered categorical data, the appropriate analysis is ordinal regression (Coe, 2002; De Groote *et al.*, 2010), which is equivalent to the proportional odds model. This model estimates the log odds ratio, or the log of the ratio of the odds of that treatment having a high score rather than low to the odds of the control having a high score rather than low.

First, the following simple model was estimated:

$$\log \left(\frac{P(Y \leq j)}{1 - P(Y \leq j)} \right) = \tau_j + \beta' \mathbf{x} + \lambda' \mathbf{s} + \mu' \mathbf{f} \quad (1)$$

The dependent variable Y_i is an ordinal measure of the overall evaluation score of a farmer i , using a score from A (very good) to E (very poor). For data analysis, it was converted to 1 (very poor) to 5 (very good). x , s and f are vectors of independent variables, τ is a cut point and β is a vector of logit coefficients. The independent variable consists of three vectors of binary variables or dummies, which are used to capture the different pesticide treatments (x), seeds (s) and different participants (f). For each of these groups, the categories are linear combinations of one another and, therefore, one category has to be omitted for each group. The first vector x consists of a dummy for each of the three different pesticide treatments (Nimbecidine, Demin Fit and Looper Kill) with the exception of control (standard maize seed without pesticide). The second vector s has a dummy for one seed (Fortenza coated with, standard seed is the reference category). The third vector f contains a binary variable for each participant except one, to capture the correlation of evaluations of the same farmer for different pesticide treatments. The estimation of this basic model provides log odds ratios for the different pesticide treatments compared to the control, while controlling seed and farmer effect.

In order to analyze whether there are differences in the appreciation of specific pesticide treatments between seeds, cross effects were introduced in the following model:

$$\log \left(\frac{P(Y \leq j)}{1 - P(Y \leq j)} \right) = \tau_j + \beta' \mathbf{x} + \lambda' \mathbf{s} + \mathbf{s}' \mathbf{A}_{sx} \mathbf{x} + \mu' \mathbf{f} \quad (2)$$

The matrix A_{sx} has a column for each of the seed variables in vector s , and a row for each of the pesticide treatments in vector x , and each element represents a cross effect of the seed with that particular pesticide treatment. In this model, the β coefficients are to be interpreted as the log odds ratios for the different pesticide treatments for the reference category (control), while the cross effects are for the differences in log odds ratios between the different seeds.

The ordinal regression in equation 3 was also used to determine if there were any significance differences in farmer likeness of different maize criteria. Among the maize criteria were; germination, vigor, stalk thickness, number of cobs, cob size, grain size and yield.

$$\log \left(\frac{P(Y \leq j)}{1 - P(Y \leq j)} \right) = k_j + \beta' \mathbf{x} + \lambda' \mathbf{s} + \mu' \mathbf{f} \quad (3)$$

In the regression model (3), Y_i is the likeness score for the maize criteria, ranging from 1 (dislike very much) to 5 (Like very much). In the above model, β' is the log odds ratios, \mathbf{x} is the maize variety (treated or untreated hybrids and local varieties), \mathbf{f} represents the different farmers, λ' is a dummy for control or base (FD treated maize was used as the control or the base), k_j is the cutoff for each treatment and \mathbf{s} represents the different maize fields.

The ordinal regression model was further used to analyze the severity of attack in the fields of the surveyed farmers, both treatment and control farmers. The FAW severity was measured on a 4 point Likert scale from 0 (very low infestation) to 3 (very high infestation). In equation (4), Y_i is the score for FAW severity by farmers, \mathbf{x} is the treatment (different maize varieties).

$$\log\left(\frac{P(Y \leq j)}{1-P(Y \leq j)}\right) = k_j + \beta' \mathbf{x} + \lambda' \mathbf{s} + \mu' \mathbf{f} \quad (4)$$

The ordinal regression model was further used to determine farmer characteristics influencing the scores for FAW infestation in the fields of the surveyed farmers, both treatment and control farmers. The FAW severity was measured on a 4 point Likert scale from 0 (very low infestation) to 3 (very high infestation). In equation (5), Y_i is the score for FAW severity by farmers, \mathbf{x} is a vector of independent variables; Gender, age, experience, education, cattle owned, farmer type (treatment or control), land owned, land farmed, land under maize, income.

$$\log\left(\frac{P(Y \leq j)}{1-P(Y \leq j)}\right) = k_j + \beta' \mathbf{x} + \lambda' \mathbf{s} + \mu' \mathbf{f} \quad (5)$$

The mixed regression model was used to determine the differences in time of FAW attack to the different maize varieties, both treatment and control farmers. The maize varieties were in three categories; the FD treated maize, untreated hybrids and local maize varieties. The time of FAW attack was measured in weeks after germination, that is, when the farmer observed first FAW attack to the Maize. The regression model was specified as follows:

$$Y_{ij} = a + bx_{ij} + u_i + e_{ij} \quad (6)$$

Where i is an index for individuals, j is an index for time. Y_{ij} and x_{ij} are outcome and predictor variables which are both time and individual varying, u_i is the random effect specific to respondent i , e_{ij} is the remaining error term (Breusch & Pagan, 1980; Errickson. (n.d.)). In the regression model above, Y_{ij} is time of FAW attack and x_{ij} is the maize variety (i.e Fortenza

treated maize, untreated hybrid and local maize varieties), Fortenza treated maize was used as the base to compare time of FAW attack with untreated hybrid and local maize varieties.

The Lagrange multiplier test was further used to test the appropriateness of the random-effects estimator (Breusch and Pagan. 1980). The null hypothesis states that model residuals do not contain individual specific error components. If no error components, then the model is appropriate for analysis. The results of the test indicated that the model was appropriate for analysis, see appendix 4.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

Chapter four presents the results from the analysis of the data that was collected during the surveys on the effectiveness of fortanza duo technology in controlling fall army worms. The presentation of the results starts with demographic characteristics of the respondents, then the descriptive analysis and lastly the statistical analysis in line with the research objectives.

Table 4.1. Characteristics of the participants for farmer evaluation

	Host farmers (N = 7)		Invited farmers (195)	
	Mean	St. Dev	Mean	St. Dev
Gender (Male)	71%		55%	
Age in years	52.0	9.4	41.3	13.3
Years of Experience in Farming	22.6	11.5	19.4	12.7
Purchased Improved Seeds	85.7%		72.3%	
Years of formal Education	6.6	1.5	7.4	2.6
Invited Farmers Participants'	3%		97%	
Total Land owned (ha)	9.6	6.0	10.8	14.8
Land under maize production (ha)	1.7	1.0	1.2	1.0
Experienced FAW in Fields	100%		88.7%	
Number of cattle owned	0	0	0.91	2.94
Number of Oxen	0	0	0.15	0.58
Used oxen to plough	14%		21%	

Author, 2020.

For the on-farm trials, the host farmers as well as neighbors and farmers from the village were invited to evaluate the trials, and some background information was collected before the actual trials. The host farmers were a few years older than the invited farmers, 52 vs 41 years of age, and were mostly men (71%), while the gender for the invited farmers was; 55% male, 45% female. More host farmers purchased improved maize seed (86%) than the invited farmers (72%). Otherwise, participants were similar, with about 20 years of farming experience and

seven years of formal education. They owned about 10 hectares of land on average, of which only a small portion was planted in maize: 1.7 ha for the host farmers and 1.2 ha for the invited farmers.

Table 4.2 Social and demographic characteristics of the participants in the farmer survey

Variable	Treatment (N = 153)		Control (N = 162)		statistical tests (P-Values)
	Mean	St Dev	Mean	St Dev	
Male	70%		52%		0.001 (Chi2 test)
Age in years	49.4	11.1	45.8	14.2	0.0147 (t-test)
Years of Experience in Farming	27.1	12.1	25	14.4	0.1529 (t-test)
Level of Education (years)	8	3.5	6.7	3.1	0.0001 (t-test)
Total household (1000 ZMK/year)	20	357	10	17	0.0015 (t-test)
Total Land owned (ha)	11.4	13.1	8.6	12.9	0.0632 (t-test)
Total Land under cultivation (ha)	4.7	4.1	3.7	4.5	0.0317 (t-test)
Land under maize production (ha)	2.8	3.5	1.8	2	0.0021 (t-test)
Number of cattle owned	3.6	5.2	2.5	4.5	0.0612 (t-test)
Number of Oxen	1.2	1.8	0.7	1.1	0.0020 (t-test)
Use oxen	0.6	0.5	0.5	0.5	
Category / Type of Participant	49%	-	51%	-	

Author, 2020.

In the second phase of the study, 153 host farmers were visited and interviewed, and 162 nearby control farmers. Treatment farmers comprised more men than control farmers (70% vs 52%) and they were generally older (29 vs. 46 years old). There was no significant difference in terms of farming experience between treatment and control farmers (27 vs 25 years), but treatment farmers had one year more of education than control farmers (8 vs. 7 years). Most importantly,

the household income of treatment farmers was more than 20,000 ZMK per year, double that of the control farmers. Similarly, treatment farmers cultivated more land than control farmers, and had a larger maize area (2.8 ha vs. 1.8 ha). Treatment farmers also owned more oxen, although the use of oxen was equally low for both groups.

4.1.1 Criteria farmers consider important when choosing pesticides

Framers were asked to score the criteria they consider important in choosing pesticides, on a scale of 0 (not important) to 3 (very important). As shown in figure 4.1 below; farmers listed four criteria as important. They gave the highest scores to convenience and health risk (both with an average score of 2.7), followed by cost and labor requirements. One criterion, odor, got the lowest score, hence considered not important. The criteria the farmers scored high and important are favorable for fortenza, fortenza duo is considered to be more convenient and reduce health risks. Fortenza duo is also expected to reduce costs and labour requirements which come as a result of frequent spray of pesticides, and as the product is in the seed coating, odor is likely not to be a problem.

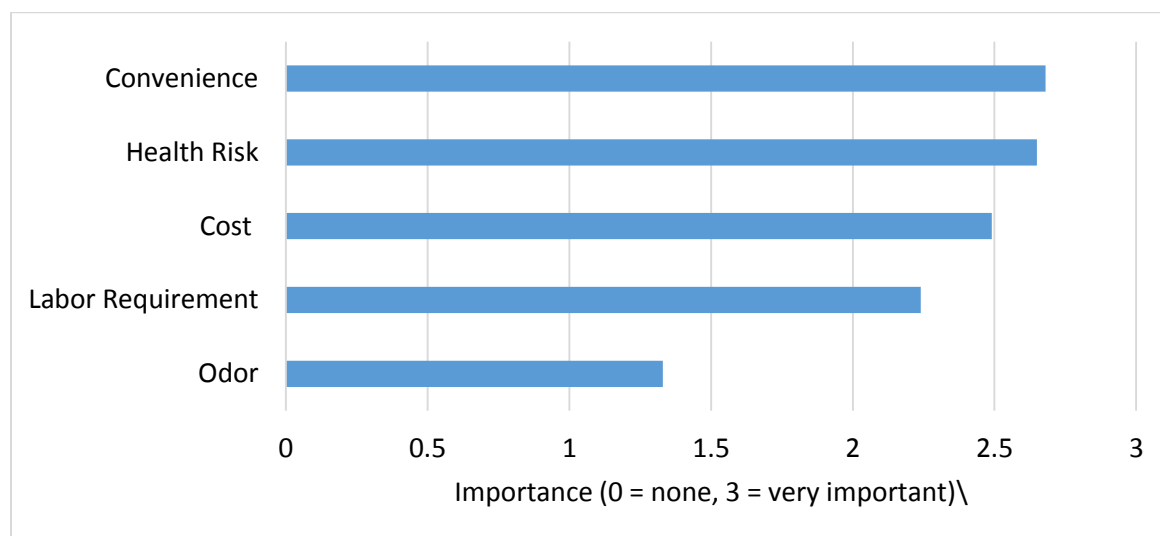


Figure 4.1 Importance of criteria to the farmers for pesticide choice: N = 202.

Author, 2020.

4.1.2 Criteria farmers consider important when selecting maize variety

Farmers were asked to identify the criteria they consider important when selecting maize varieties, and give them an importance score, from 0 = not important, to 3 = very important. Farmers identified seven criteria as important. The most important ones were yield, grain weight

and germination (all with an average of 3.0), followed by drought resistance and number of cobs (both 2.9) and grain size (2.8), highly and important. Maize variety resistant to fall army worm was ranked as important (average 2.6), and ranked 7th among the important criteria. It's important that the maize varieties supplied to the farmers are able to meet these criteria that are important to the farmers.

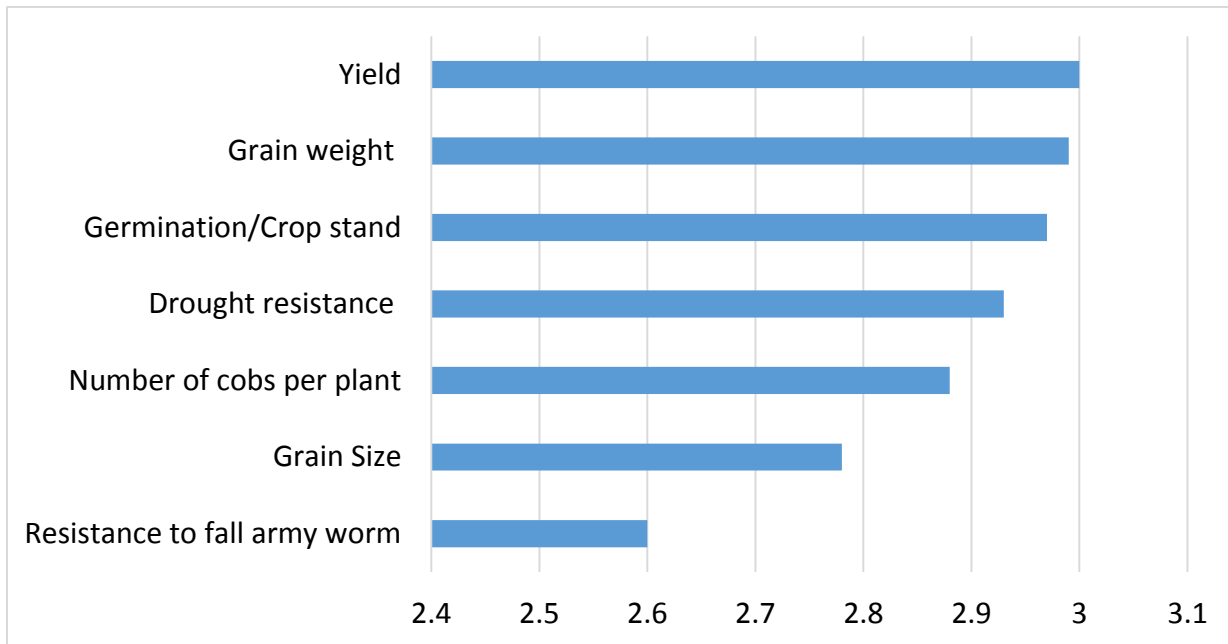


Figure 4.2: Importance of criteria for maize variety selection: N = 202

Author, 2020.

4.1.3 Farmer evaluation of Fortenza treated maize based on different criteria

Next, farmers were asked to inspect the demonstrations of Fortenza and to score the plots on the different criteria, on a score of 1 (dislike very much) to 5 (like very much). Farmers scored Fortenza duo treated maize higher than average for several criteria, in particular liked for germination/crop stand, resistance to FAW and stalkborer, and barrenness level. Farmers also gave good scores for height, grain size, and biomass, although for these criteria the scores were similar to the average overall score. However, the scores for yield, cob size, stalk thickness and number of cobs was lower than that for the overall evaluation. The results show that farmers clearly liked the resistance of the maize to FAW that Fortenza establishes. Unfortunately, we were not able to compare these results to the evaluation of control varieties, as these already had been harvested earlier.

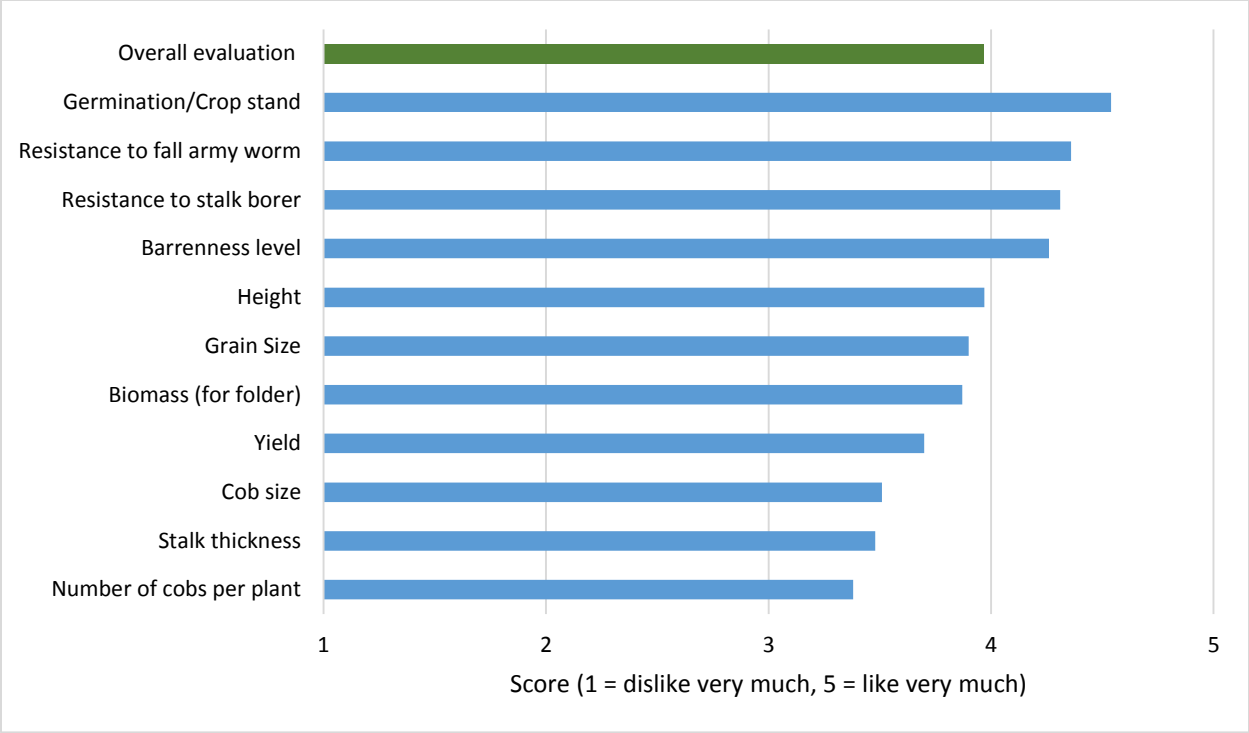


Figure 4.3: Farmers' evaluation of fortenza treated maize on the different criteria they find important

Author, 2020.

4.1.4 Farmer evaluation of Fortenza treated maize, hybrid and local varieties

In the second visit, a subset of treatment farmers were asked to score the maize varieties they had planted, in particular fortenza treated variety, hybrid and local varieties. Fortenza treated maize varieties, SY6444 and SY5944, scored higher than hybrid and local varieties that were not treated with fortenza. Local maize scored lower than the mid-point (3) in terms of yield, grain size, cob size and number of cobs. Hybrid maize scored better than local maize. The results imply that fortenza treated maize outperformed the other varieties in terms of scores. See figure 4.4.

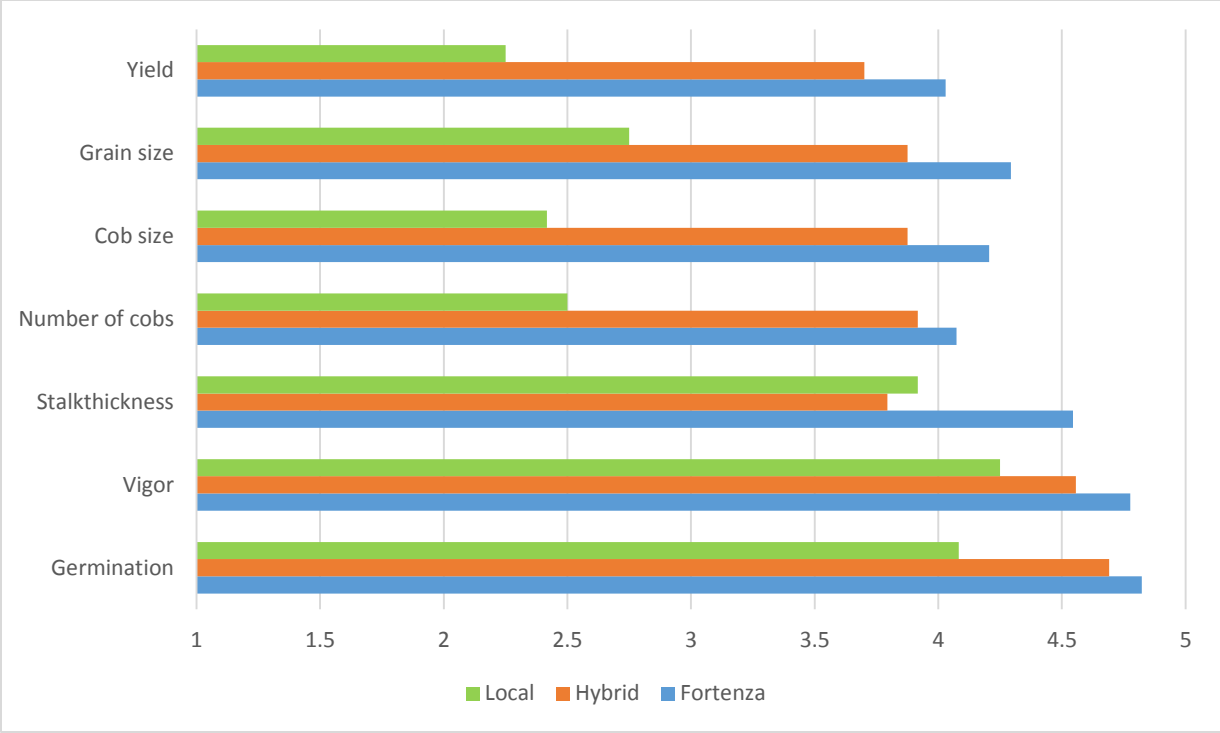


Figure 4.4: Farmer evaluation of different maize Varieties

Author, 2020.

4.1.5 FAW presence in farmers’ maize fields

Farmers were asked whether they experienced FAW attack in their maize fields or not. The question was asked to the treatment group (who planted fortenza treated variety, untreated hybrid and local varieties) and to the Control farmers who only planted untreated hybrid and local varieties. The study found that more fortenza treated maize fields had no FAW attack as compared to untreated hybrid and local maize, both in treatment and control farmers.

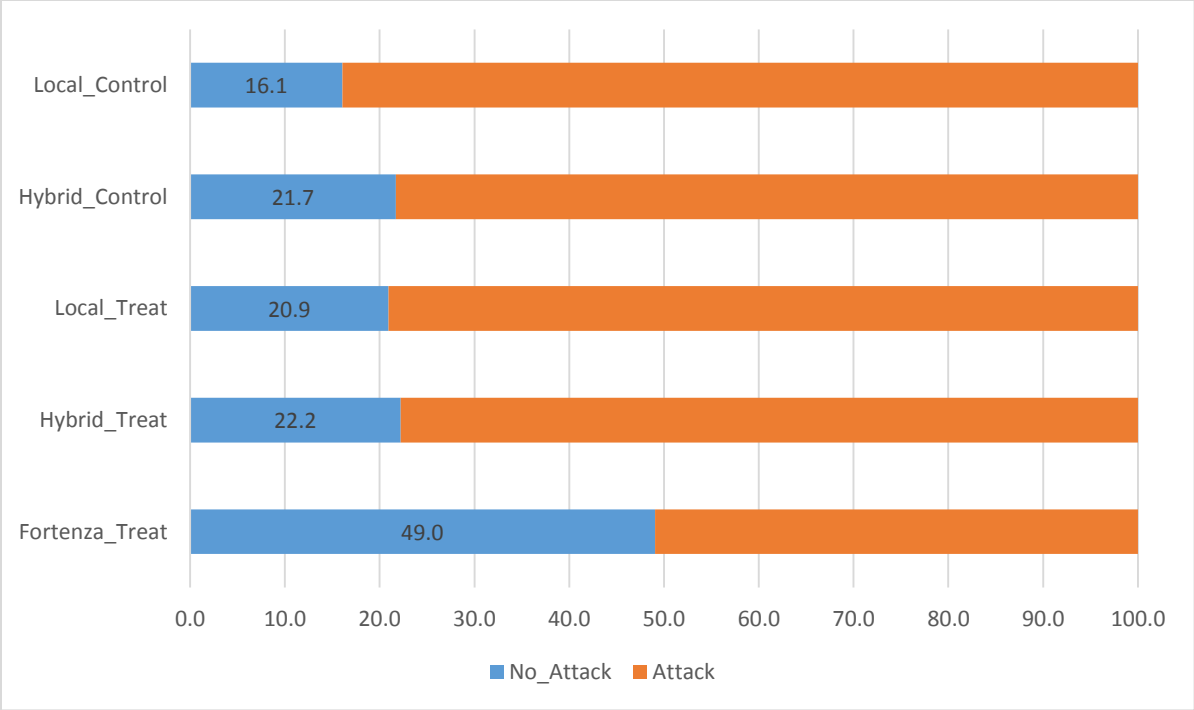


Figure 4.5: FAW presence in Farmers Fields According to farmer categories: N = 315

Author, 2020.

4.1.6 Time of FAW attack to Fortenza treated maize, hybrid and local varieties

The study also segregated the data according to treatment and control farmer categories. From the results presented in figure 4.6, for the treatment farmers, fortenza treated maize had lower attacks in the first weeks of plant germination. The attack to fortenza treated maize was also lower than the attack in hybrid and local maize varieties for control farmers. Therefore, fortenza duo helped in delaying FAW attack to the maize.

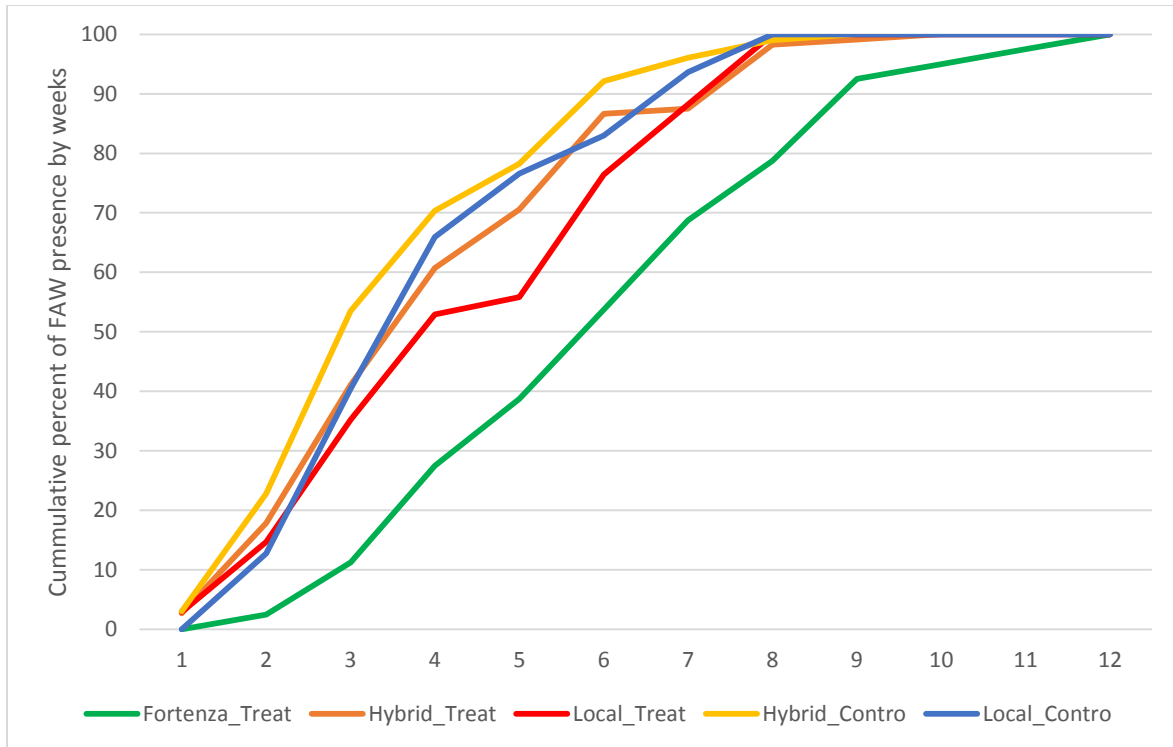


Figure 4.6: FAW attack to maize varieties with respect to time (weeks): N = 315

Author, 2020.

4.1.7 FAW severity with respect to the type of seed variety.

Farmers were asked to indicate how severe the FAW was in their fields, on a scale of 1 (very low infestation) to 4 (very high infestation). The results show that Fortenza treated maize had substantially lower levels of infestation than the hybrids. The results meant that, fortenza duo helped in reducing the severity of FAW infestation.

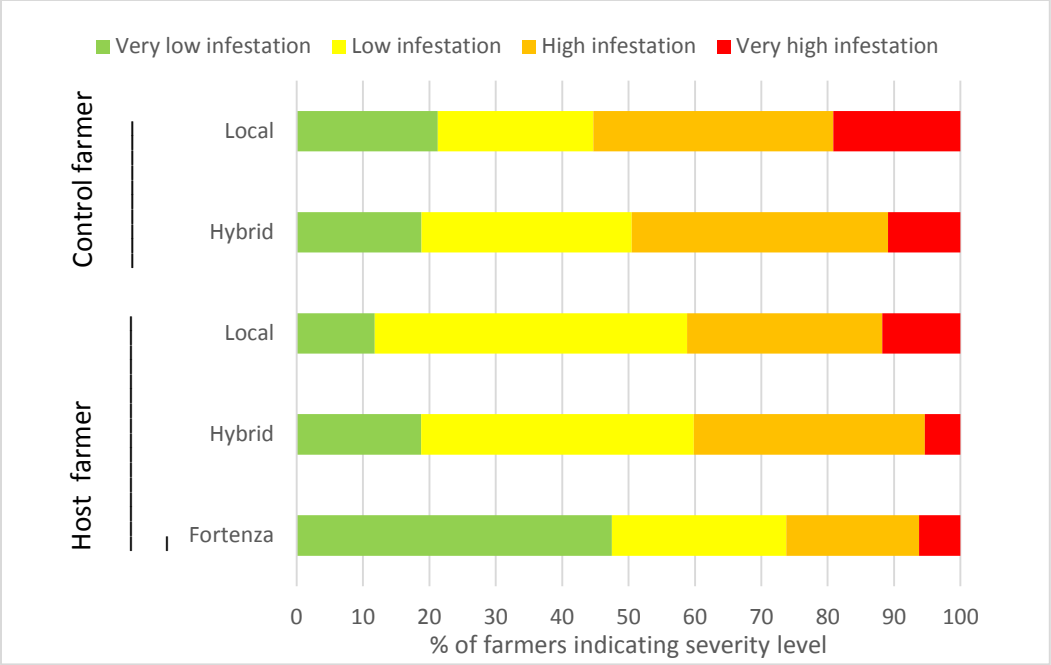


Figure 4.7: FAW severity with respect to the type of maize variety: N = 315

Author, 2020.

4.1.8 Farmers' scores for their likeness of different maize criteria

Farmers were asked to score their likeness of the maize varieties they had planted in terms of germination, vigor and stalk-thickness, number of cobs, cob-size, grain-size and yield. Three maize varieties were scored, fortenza treated maize (SY6444 and SY5944), hybrid and local maize varieties. The study used a five likert scale of; A = like very much, B = like, C = neither like nor dislike, D = dislike, E = dislike very much. The results in the figure shows that farmers score for 'like very much' was higher for fortenza treated maize than hybrid and local maize. This means that farmers liked fortenza treated maize more than the hybrid and local maize. See figure 4.8.

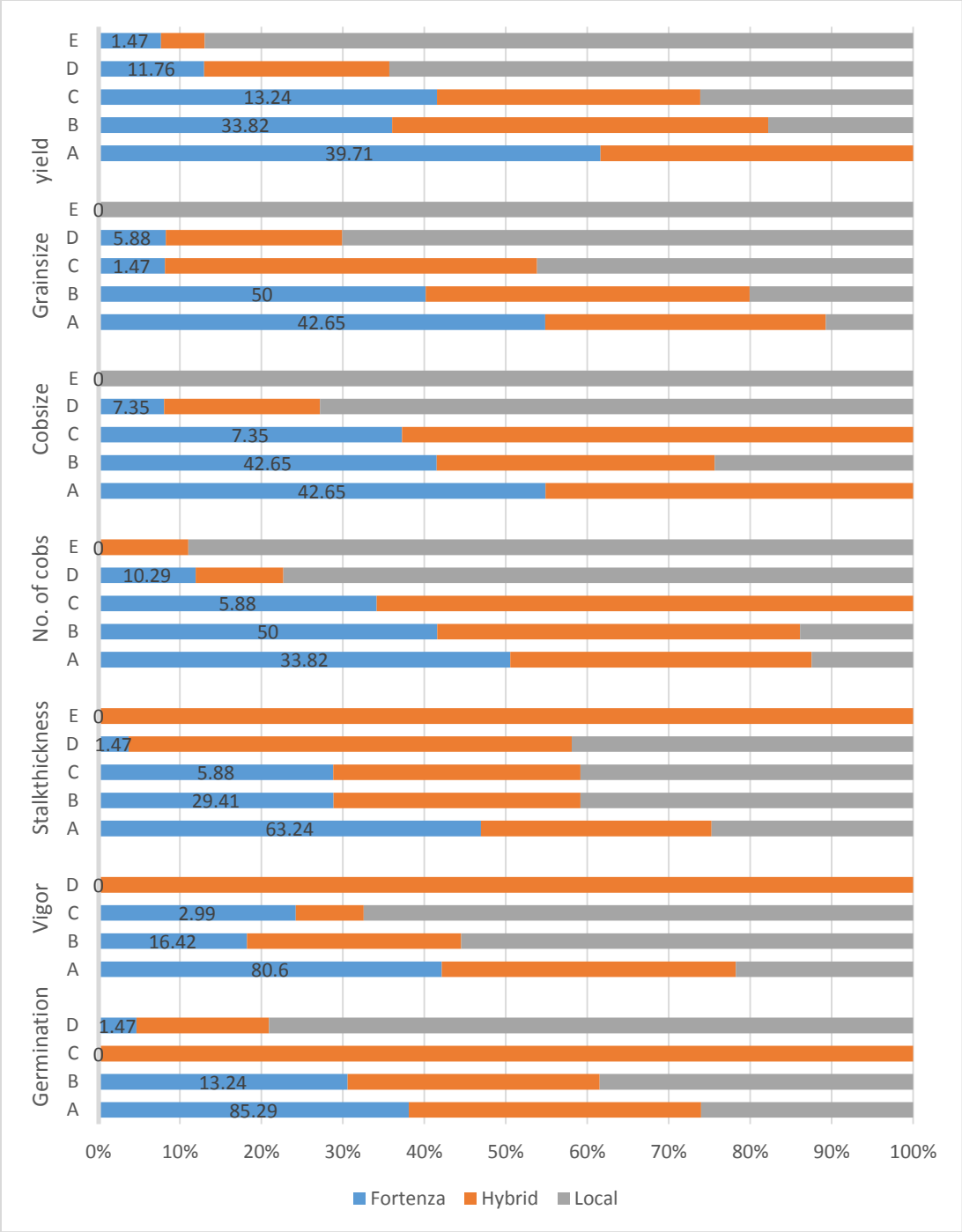


Figure 4.8 Farmers' scores for their likeness of the maize criteria for the varieties. N = 35.
 Author, 2020.

4.1.9 Mid-season on-station evaluation of Fortenza and Denim fit treatments

In the mid-season for on-station evaluation, farmers evaluated four of the treatments in the trial: the control and seed treated with Fortenza Duo, and then each with and without the insecticide Denimfit. A five-point Likert scale was used to assess four criteria: germination/crop stand, resistance to stem borers, resistance to FAW and overall. In the plots without pesticide sprays, farmers scored Fortenza significantly better than the control, with an overall score of 2.9 as compared to 2.3 for the control. Fortenza also scored substantially better for resistance to stalk borer and FAW. Interestingly, Fortenza also performed better for germination, which could be a side effect from the protection against FAW and other insects, in particular the cut worm. In the plots that were treated with Denimfit, however, there was no difference between Fortenza and the control, they both received an overall score of 4.2. Similarly, the results for the scores on the other farmer criteria were basically the same.

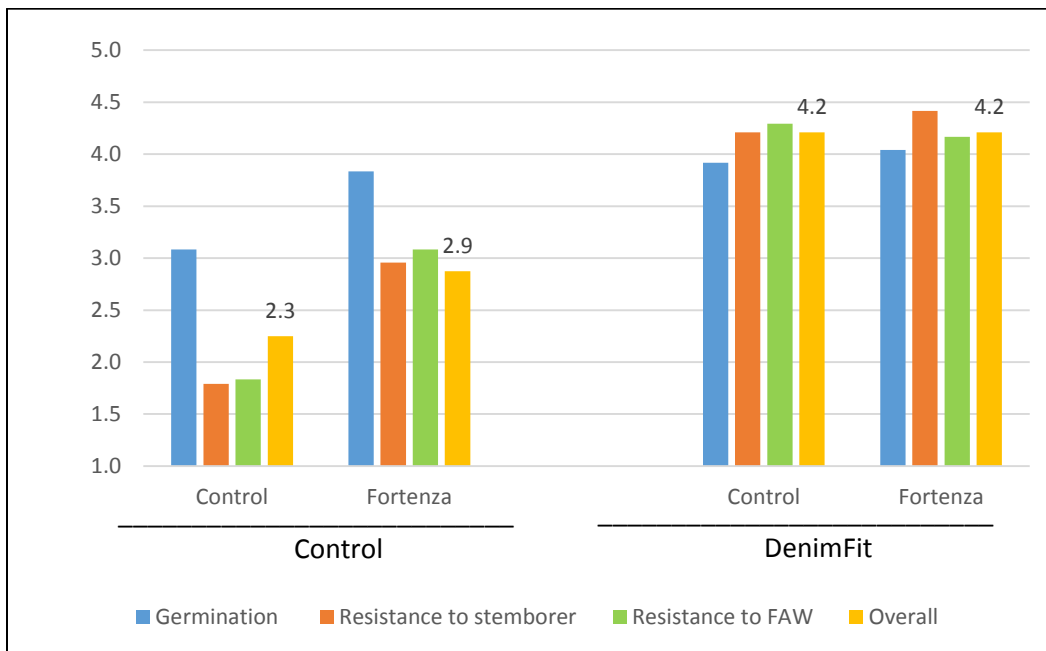


Figure 4.9 On-station farmer evaluation of Fortenza duo and DenimFit at mid-season

Author, 2020.

4.1.10 End-season on-station evaluation of the Trial

At the end season evaluation of the on-station trial, farmers were asked to evaluate all eight treatments of the hybrid maize, which included plots with other pesticide treatments not evaluated during the mid-season evaluation (Nimbecidine and Looper Kill). For the scores on FAW resistance, there was no difference between Fortenza and other treatments. On the overall evaluation, the Fortenza treatment received slightly higher scores than the control in combination with Denim fit and Looper Kill, but slightly lower scores for Nimbecidine and the control. Clearly, at the end of the season, farmers could not distinguish between Fortenza treatment and the control.

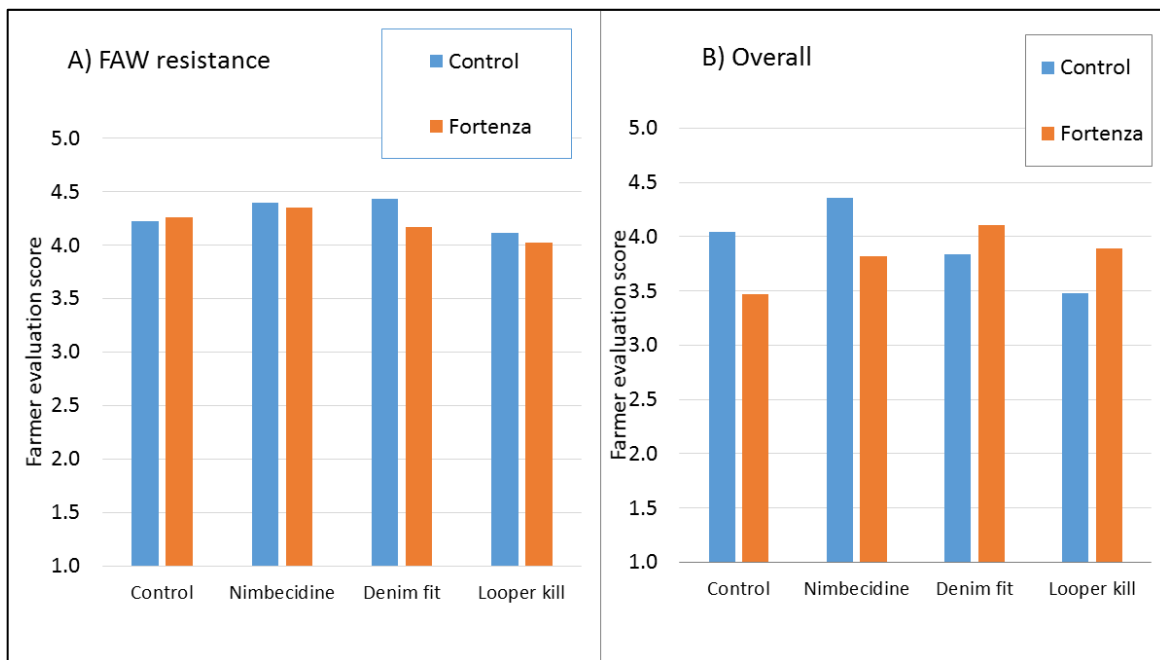


Figure 4.10 On-station evaluation of Fortenza and control, in combination with other insecticide treatments, for FAW resistance and overall

Author, 2020.

4.1.11 Statistical analysis of the farmer evaluation scores of on-station trial

Table 4.3 Ordinal regression results: Farmer evaluation of on-station trial (mid-season)

	Coefficient	Std. Err.	P>z
Fortenza coating	1.08	0.55	0.050
Denim Fit	4.26	0.74	0.000
Fortenza x Denim Fit	-0.71	0.80	0.375
/cut1	-1.71	0.52	
/cut2	0.85	0.42	
/cut3	1.89	0.47	
/cut4	5.23	0.72	
Number of observations	390		
LR chi2(4)	16.62		
Prob> chi2	0.0023		
Pseudo R2	0.0153		
Log likelihood =	-534.6332		

Author, 2020.

For statistical analysis of the farmer evaluation scores, which are ordinal categorical data, ordinal regression was used. The main factors in the analysis are Fortenza seed treatment, application of the insecticide DenimFit, and the cross effect. The analysis shows that the main effects are significant and positive, indicating that both treatments have a positive effect on overall score, although that for Denim fit is much larger than for Fortenza. Moreover, the cross effect is not significant, indicating Fortenza does not add value to the score for plots treated with both.

Table 4.4 Ordinal regression results: Farmer evaluation of on-station trial (end-season)

Main factor	Variable	FAW resistance			Overall evaluation		
		Coef.	Std. Err.	P>z	Coef.	Std. Err.	P>z
Seed	Fortenza	0.47	0.42	0.257	-1.02	0.39	0.01
Insecticide	Nimbecidine	0.52	0.41	0.201	0.40	0.39	0.311
	Looper Kill	-0.17	0.39	0.664	-1.06	0.38	0.005
	Denim Fit	0.70	0.41	0.088	-0.50	0.38	0.194
Cross-effects	Fortenza x Nimbecidine	-0.52	0.60	0.382	0.15	0.55	0.789
	Fortenza x Looper Kill	-0.72	0.58	0.212	1.71	0.54	0.002
	Fortenza x Denim Fit	-1.16	0.61	0.056	1.45	0.55	0.008
Cut-offs	/cut1	-4.57	0.54	0.000	-3.42	0.38	0.000
	/cut2	-3.21	0.43	0.000	-2.39	0.35	0.000
	/cut3	-1.95	0.40	0.000	-1.47	0.33	0.000
	/cut4	0.25	0.38	0.505	0.23	0.32	0.472
Model	Number of observations	396			390		
	Number of groups	29			29		
	/sigma2_u	1.816	0.627		0.641	0.260	
	Wald chi2(7)	12.34			23.09		
	Prob> chi2	0.090			0.002		
	Log likelihood	-411			-518		

Author, 2020.

For the on-station trial, again, ordinal regression was used for statistical analysis of the evaluation scores. The results show that the score (main effect) for FAW is positive, indicating that farmers score Fortenza higher than the control for this trait, but the effect is not significantly different from zero. For the overall evaluation, the results show that, for the main effects, Fortenza has a negative score. The interpretation is that Fortenza, without other insecticides, is not as well appreciated by farmers as the control without insecticides. This is also seen in Figure 3, Panel B. The cross effects of using Fortenza treated maize with insecticides Looper Kill and Denim Fit, are positive and significant, meaning that Fortenza improves the overall scores for these two insecticide treatments.

Table 4.5 Ordinal regression analysis on farmers evaluation of Fortenza Duo, hybrids and local varieties for different criteria (N = 35)

Group	Variable	Germination			Vigor			Stalkthickness			Number of Cobs		
		Coef.	SE	P	Coef.	SE	P	Coef.	SE	P	Coef.	SE	P
Maize Varieties	Hybrid	-0.38	0.43	0.371	-0.65	0.38	0.085	-1.22	0.31	0.000	-0.39	0.30	0.201
	Local Maize	-1.64	0.68	0.016	-1.62	0.61	0.008	-1.16	0.57	0.041	-3.16	0.70	0.000
Intercepts	/cut1	-3.32	0.45		-3.75	0.47		-4.95	0.63		-5.46	0.81	
	/cut2	-3.20	0.44		-3.37	0.43		-2.55	0.31		-2.32	0.31	
	/cut3	-1.79	0.34		-1.43	0.31		-2.11	0.29		-1.65	0.27	
	/cut4							-0.62	0.24		0.68	0.24	
Model	N Participants	35			35			35			35		
	N Observation	177			176			177			177		
	Wild Chi2(2)	5.41			7.51			16.71			22.85		
	Prob > chi2	0.067			0.0234			0.000			0.000		
	Pseudo R2	0.025			0.0276			0.038			0.0524		
	Log Likelihood	-107.7			-132.4			-209.3			-206.7		
Group	Variable	Cob-size			Grain-size			Yield					
		Coef.	SE	P	Coef.	SE	P	Coef.	SE	P			
Maize Varieties	Hybrid	-0.53	0.29	0.073	-0.86	0.31	0.005	-0.59	0.29	0.046			
	Local Maize	-3.31	0.73	0.000	-2.95	0.66	0.000	-3.19	0.70	0.000			
Intercepts	/cut1	-6.28	1.08		-6.23	1.05		-5.08	0.68				
	/cut2	-2.16	0.29		-2.58	0.32		-1.91	0.28				
	/cut3	-1.52	0.26		-2.13	0.29		-1.26	0.26				
	/cut4	0.20	0.23		0.22	0.23		0.46	0.24				
Model	N Participants	35			35			35					
	N Observations	177			177			176					
	Wild Chi2(2)	26			23.64			25.42					
	Prob > chi2	0.000			0.000			0.000					
	Pseudo R2	0.0569			0.0564			0.0529					
	Log Likelihood	-215.4			-197.8			-227.4					

4.1.12 Ordinal regression analysis on farmer evaluation of Fortenza Duo, hybrids and local varieties for different criteria

A subset of 35 treatment farmers who planted fortenza treated maize were asked to score the new fortenza treated maize variety, and also their other hybrids and their local or recycled varieties. For the analysis, we used ordinal regression, where the coefficient represents the log odds ratio, or the log of the odds that one variety is preferred over the other. The dependent variables are the scores for the different traits, while the independent variable is the type of variety: Fortenza, hybrid and local variety. In this analysis, Fortenza duo treated maize was used as the reference group. We found that all criteria, farmers gave Fortenza the highest score, and local or recycled varieties the lowest. Fortenza scored significantly higher than local or recycled varieties for all criteria. However, when comparing Fortenza to the hybrids, the coefficients are only significant for Vigor (10%), Stalk thickness (1%), cob size (10%), grain size, and yield (5%).

Table 4.6 Mixed regression analysis of time FAW was observed among the maize varieties

Variable	Coef.	Std. Err.	P>z	[95% Conf.
Hybrid maize seed	-2.1874	0.26181	0.000	-2.7005
Local maize seed	-1.8400	0.31581	0.000	-2.4589
_Cons	6.3134	0.2247	0.000	5.8729
sigma_u	0.3562463			
sigma_e	1.8915261			
Rho	0.0342561	(fraction of variance due to u_i)		
Number of obs	374			
Number of groups	270			
Within	0.1737			
Between	0.1426			
Overall	0.1616			
Wald chi2(2)	70.80			
Prob > chi2	0.000			

Fortenza used as control or base.

Author, 2020.

A mixed regression analysis (with random effects for farmers) was used to determine if there was any statistical difference in the time when FAW attacked the maize. Fortenza treated maize variety was used as a control in this analysis. The study found that in hybrid maize varieties, FAW attacked 2.2 weeks earlier than in Fortenza treated maize plots. For local maize varieties the difference was slightly less, 1.8 weeks. These differences were highly significant, indicating that fortenza duo delays the attack of FAW to the crops by over two weeks as compared to local varieties and untreated hybrids.

4.1.13 Assessing the time of FAW attack for hybrid and local maize varieties for treatment farmers

Table 4.7 Cross effect of treatment farmer on the time of FAW attack for hybrid and local maize varieties (N = 315)

Time_FAW_Observed	Coef.	Std. Err.	P>z	[95% Conf.
Main effects				
Hybrid maize seed	-2.47398	0.300295	0.000	-3.06255
Local maize seed	-2.04948	0.368563	0.000	-2.77185
Cross effects				
Treatment_Hybrid	0.515202	0.275666	0.062	-0.02509
Treatment_Local	0.464627	0.451514	0.303	-0.42032
_constant	6.326907	0.224209	0.000	5.887465
sigma_u	0.292547			
sigma_e	1.900213			
rho	0.023153			
Number of obs	374			
Number of groups	270			
within	0.1723			
between	0.1515			
overall	0.1715			
Wald chi2(4)	76.06			
Prob > chi2	0.000			

Fortenza used as control or base

Author, 2020.

From the three maize varieties; fortenza treated maize, hybrid and local varieties, the study employed mixed regression to determine the difference in time of FAW attack among the three maize varieties (main effect).Further in this analysis, the study included a cross effect analysis of hybrid and local maize varieties for the treatment farmers (Hybrid X treatment and Local X

treatment). From the results in table 11, the cross effect (hybrid X treatment) is not significant; therefore, the significant difference in time of FAW attack in hybrid maize variety does not only depend on treatment farmer but on both (treatment and control farmers). The cross effect (Local X treatment) is not significant, therefore, the difference in time of FAW attack that is observed between local maize and fortanza treated maize does not depend only on treatment farmer but on both (control and treatment farmers).

4.1.14 Assessing FAW severity among the maize varieties

Table 4.8 Ordinal regression analysis of FAW severity among the maize varieties: N = 315

FAW_Severity	Coef.	Std. Err.	P>z
Hybrid maize seed	1.0784	0.2524	0.000
Local maize seed	1.3423	0.3030	0.000
/cut1	-0.2518	0.2191	
/cut2	1.2833	0.2310	
/cut3	3.2598	0.2795	
Number of obs	374		
LR chi2(2)	23.85		
Prob > chi2	0.0000		
Pseudo R2	0.0246		
Log likelihood =	-473.6424		

Fortenza used as control or base

Author, 2020.

Ordinal regression analysis was used to determine if there was any statistical significant difference in FAW severity among the varieties. Three maize varieties were compared, i.e., fortanza treated maize variety, hybrid maize and local maize varieties, with fortanza as the control. The results show a significant difference between Fortenza and the other varieties, indicating that the severity of attack was higher in the other varieties as compared to fortanza treated variety. In other words, the results imply that Fortenza Duo reduces the severity of FAW infestation as compared to non-treated hybrids and local varieties.

4.1.15 Assessing whether the observed difference in FAW severity is due to treatment farmers

Table 4.9 Difference in FAW severity scores among varieties, with a cross effect to the treatment farmer (N = 315).

FAW_Severity	Coef.	Std. Err.	P>z	[95% Conf.
Main effects				
Hybrid maize seed	1.236194	0.286828	0.000	0.674022
Local maize seed	1.487178	0.359068	0.000	0.783417
Cross effects				
Treatment_Hybrid	-0.28549	0.246196	0.246	-0.76803
Treatment_Local	-0.3069	0.412267	0.457	-1.11493
/cut1	-0.25369	0.219196		-0.68331
/cut2	1.285889	0.23117		0.832804
/cut3	3.274331	0.280283		2.724988
Number of obs	374			
LR chi2(4)	25.75			
Prob > chi2	0.000			
Pseudo R2	0.0265			

Fortenza used as control or base.

Author, 2020.

An ordinal regression analysis was conducted to determine if the difference in scores of FAW severity observed can be attributed to treatment farmers only, this was done by including cross effects (treatment X hybrid, and treatment X local) to the analysis. From the results presented in table 4.11, the coefficient of the cross effect (treatment X hybrid) was not significant, hence, the observed severity score can be attributed to both (treatment and local farmers), and not to treatment alone. Since the coefficient for the cross effect (treatment X local) was also not significant, hence, the observed difference score was attributed to both (treatment and control farmers).

4.1.16 Farmer demographic characteristics influencing FAW severity Scores

Table 4.10 Farmer demographic characteristics influencing the Scores for FAW infestation

					Number of	
					obs	238
					LR chi2(10)	28.98
					Prob > chi2	0.0013
					Pseudo R2	0.0465
Log likelihood = -297.03113						
FAW severity	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
gender	-0.4631886	0.262519	-1.76	0.078	-0.977717	0.05134
age	0.0108017	0.013348	0.81	0.418	-0.01536	0.03696
experience	-0.0290412	0.013123	-2.21	0.027	-0.0547612	-0.0033
education	-0.0187439	0.035613	-0.53	0.599	-0.0885434	0.05106
cattleowned	-0.0663488	0.027855	-2.38	0.017	-0.1209429	-0.0118
farmercat	0.5972915	0.260632	2.29	0.022	0.0864623	1.10812
totallandowned	-0.0057304	0.015706	-0.36	0.715	-0.0365137	0.02505
landundercultivation	0.0473506	0.057068	0.83	0.407	-0.0645004	0.1592
landundermaizeprod	0.0146293	0.074395	0.2	0.844	-0.131183	0.16044
income	-5.26E-06	3.82E-06	-1.38	0.168	-0.0000127	2.22E-6
/cut1	-1.189325	0.729063		-2.6183	0.2396115	
/cut2	0.3451198	0.723896		-1.0737	1.76393	
/cut3	2.349624	0.747636		0.88428	3.814964	

Author, 2020.

An ordinal logistic regression analysis was performed to determine the farmer characteristics influencing FAW severity scores (0. Very low infestation, 1. Low infestation, 2. High infestation, 3. Very high infestation). The results indicated that been male (male =1, female = 0), a farmer is more likely to score low infestation of FAW (0.078 p-value). Farmers with more years of farming experience are more likely to score low infestation of FAW (0.027 p-value). Owning more cattle, a farmer is likely to score low infestation of FAW (0.017 p-value). Been a control farmer (control farmer =2, treatment farmer =1), a farmer is more likely to score high infestation of FAW (0.022 p-value). The other variables were not significant in influencing scores for FAW severity.

Table 4.11 Marginal effects for FAW infestation scores

Very low infestation							
variable	dy/dx	Std. Err.	z	P>z	[95%	C.I.]	X
gender*	0.0807691	0.0447	1.81	0.071	-0.00684	0.16838	0.605042
age	-0.0019346	0.00239	-0.81	0.419	-0.00663	0.002759	47.2311
experience	0.0052014	0.00237	2.19	0.028	0.000551	0.009852	26.4538
education	0.0033571	0.00637	0.53	0.598	-0.00913	0.015846	6.63445
Cattle owned	0.0118835	0.00503	2.36	0.018	0.002025	0.021742	4.20168
Farmer type	-0.1069783	0.04668	-2.29	0.022	-0.19847	-0.015489	1.38235
Land owned	0.0010263	0.00281	0.36	0.715	-0.00449	0.006539	7.62682
Land-farmed	-0.0084808	0.01022	-0.83	0.407	-0.02851	0.011553	4.05765
Land for maize	-0.0026202	0.01333	-0.2	0.844	-0.02874	0.023503	2.22743
income	9.43E-07	0	1.38	0.168	-4.00E-07	2.30E-06	12777.8
Low infestation							
variable	dy/dx	Std. Err.	z	P>z	[95%	C.I.]	X
gender*	0.0320162	0.02123	1.51	0.132	-0.00959	0.073623	0.605042
age	-0.000686	0.00087	-0.79	0.43	-0.00239	0.001019	47.2311
experience	0.0018445	0.00099	1.86	0.063	-0.0001	0.003791	26.4538
education	0.0011905	0.0023	0.52	0.605	-0.00332	0.005699	6.63445
Cattle owned	0.0042139	0.00217	1.94	0.052	-0.00004	0.008468	4.20168
Farmer type	-0.037935	0.02052	-1.85	0.065	-0.07816	0.002286	1.38235
Land owned	0.0003639	0.00101	0.36	0.717	-0.00161	0.002334	7.62682
Land-farmed	-0.0030073	0.00375	-0.8	0.422	-0.01035	0.004334	4.05765
Land for maize	-0.0009291	0.00473	-0.2	0.844	-0.0102	0.00834	2.22743
income	3.34E-07	0	1.26	0.207	-1.80E-07	8.50E-07	12777.8
High infestation							
variable	dy/dx	Std. Err.	z	P>z	[95%	C.I.]	X
gender*	-0.0743458	0.04195	-1.77	0.076	-0.15657	0.007875	0.605042
age	0.0017633	0.00219	0.81	0.421	-0.00253	0.006054	47.2311
experience	-0.0047407	0.00221	-2.15	0.032	-0.00907	-0.000412	26.4538
education	-0.0030597	0.00583	-0.53	0.599	-0.01448	0.00836	6.63445
Cattle owned	-0.0108307	0.00468	-2.31	0.021	-0.02001	-0.00165	4.20168
Farmer type	0.0975016	0.04406	2.21	0.027	0.011147	0.183856	1.38235
Land owned	-0.0009354	0.00257	-0.36	0.715	-0.00597	0.004095	7.62682
Land-farmed	0.0077295	0.00936	0.83	0.409	-0.01061	0.026065	4.05765
Land for maize	0.0023881	0.01215	0.2	0.844	-0.02142	0.026196	2.22743
income	-8.59E-07	0	-1.36	0.173	-2.10E-06	3.80E-07	12777.8
Very high infestation							
variable	dy/dx	Std. Err.	z	P>z	[95%	C.I.]	X
gender*	-0.0384395	0.02338	-1.64	0.1	-0.08426	0.007383	0.605042
age	0.0008574	0.00106	0.81	0.42	-0.00123	0.002943	47.2311
experience	-0.0023052	0.00109	-2.12	0.034	-0.00443	-0.000178	26.4538
education	-0.0014878	0.00283	-0.53	0.599	-0.00704	0.004065	6.63445
Cattle owned	-0.0052666	0.00235	-2.24	0.025	-0.00987	-0.000669	4.20168
Farmer type	0.0474117	0.02175	2.18	0.029	0.004789	0.090034	1.38235
Land owned	-0.0004549	0.00125	-0.36	0.716	-0.0029	0.001992	7.62682
Land-farmed	0.0037586	0.00456	0.82	0.41	-0.00518	0.012699	4.05765

Land for maize	0.0011612	0.00591	0.2	0.844	-0.01042	0.012739	2.22743
income	-4.18E-07	0	-1.35	0.177	-1.00E-06	1.90E-07	12777.8

Author, 2020

Been male, a farmer has 8.08% more likely to score very low infestation of FAW, 7.43% less likely to score high infestation of FAW, 3.84% less likely to score very high infestation of FAW. Having more years of farming experience, a farmer has 0.52% more likely to score very low infestation of FAW, 0.18% more likely to score low infestation, 0.47% less likely to score high infestation and 0.23% less likely to score very high infestation of FAW. Owning more cattle, a farmer is 1.19% more likely to score very low infestation of FAW, 0.42% more likely to score low infestation, 1.08% less likely to score high infestation of FAW and 0.53% less likely to score very high infestation of FAW. Been a control farmer type (treatment farmer = 1, control farmer = 2), a farmer is 10.7% less likely to score very low infestation of FAW, 3.79% less likely to score low infestation, 9.75% more likely to score high infestation, and 4.74% more likely to score very high infestation of FAW.

4.2 Discussion of the Findings

The arrival of fall army worm (FAW) in Africa has the potential to cause maize yield losses from 8.3 to 20.6 million tonnes per annum (21-53% of production), valued at US\$ 2.4 - 6.2 billion, if left uncontrolled (Abrahams et al., 2017; Day et al., 2017). FAW has been reported to be a big threat to food security in sub-saharan African countries (Devi, 2018). Crop productivity is low in Zambia and many other African countries. The arrival of FAW in Zambia has therefore made the situation worse for the farmers, as it has increased costs for the farmers by purchasing of pesticides as well as increased labour demand by frequent spraying of the pest. However, Syngenta developed a seed coating insecticide called Fortenza duo. Fortenza duo has been indicated by the manufacturer to delay and reduce FAW attack to maize and other crops. Before rolling out and encourage the farmers to adopt this technology in the country, it's important to carry out farmer evaluation of fortenza duo technology to assess its effectiveness, and that was the focus of this study.

4.2.1 Farmers' preference for Fortenza duo treated maize as compared to other maize varieties

Farmers were asked to inspect the demonstrations of Fortenza and to score the plots on the different criteria. From the findings, fortanza duo treated maize was scored higher than average for several criteria. In particular, farmers liked more the germination/crop stand, resistance to FAW and stalkborer, and barrenness level of the fortanza treated maize. Farmers also gave good scores for height, grain size, and biomass, although for these criteria the scores were similar to the average overall score. However, the scores for yield, cob size, stalk thickness and number of cobs was lower than that for the overall evaluation. The results show that farmers clearly liked the resistance of the maize to FAW that Fortenza establishes.

A subset of treatment farmers (farmers who planted fortanza treated maize) were asked to score the maize varieties they had planted, in particular fortanza treated variety, hybrid and local varieties. The study found that fortanza treated maize varieties, SY6444 and SY5944, scored higher than hybrid and local varieties that were not treated with fortanza. Local maize scored lower than the mid-point (3) in terms of yield, grain size, cob size and number of cobs. Hybrid maize scored better than local maize. Therefore, fortanza treated maize outperformed the other varieties in terms of scores, hence, fortanza treated maize was found to be more preferred as compared to other varieties, based on likeness scores.

From a subset of 35 treatment farmers who planted fortanza treated maize and also their other hybrids and their local or recycled varieties, using ordinal regression the study found that for all criteria, farmers gave Fortenza the highest score, and local or recycled varieties the lowest. Fortenza scored significantly higher than local or recycled varieties for all criteria. However, when comparing Fortenza to the hybrids, the coefficients are only significant for Vigor (10%), Stalk thickness (1%), cob size (10%), grain size, and yield (5%). These results imply that fortanza treated maize was statistically more preferred than the hybrid and the local maize.

4.2.2 Farmer demographic characteristics influencing FAW severity scores

Based on the results from the ordinal logistic regression analysis, the farmer characteristics influencing FAW severity scores (0. Very low infestation, 1. Low infestation, 2. High infestation, 3. Very high infestation) is gender, experience, owning cattle and farmer type (treatment or control farmer). Been male a farmer is more likely to score low infestation of FAW. Been male, a farmer has 8.08% more likely to score very low infestation of FAW, 7.43% less likely to score high infestation of FAW, 3.84% less likely to score very high infestation of FAW. Farmers with more years of farming experience are more likely to score low infestation of FAW. Having more years of farming experience, a farmer has 0.52% more likely to score very low infestation of FAW, 0.18% more likely to score low infestation, 0.47% less likely to score high infestation and 0.23% less likely to score very high infestation of FAW. Owning more cattle, a farmer is likely to score low infestation of FAW. With owning more cattle, a farmer is 1.19% more likely to score very low infestation of FAW, 0.42% more likely to score low infestation, 1.08% less likely to score high infestation of FAW and 0.53% less likely to score very high infestation of FAW. Been a control farmer (control farmer =2, treatment farmer =1), a farmer is more likely to score high infestation of FAW. Been a control farmer, a farmer is 10.7% less likely to score very low infestation of FAW, 3.79% less likely to score low infestation, 9.75% more likely to score high infestation, and 4.74% more likely to score very high infestation of FAW. A study by Musemwa (2013) found that age of household head, excellent production knowledge and level of specialization affected technical efficiency of the farmers. Among the factors affecting agricultural production Bihon (2015) found that landholding size, possession of oxen, village distance to the district market, and average distance of plots from the homestead are significant factors. However, this study did not find the significance of age, education, landholding size in influencing management outcome of FAW severity under the new control technology (Fortenza duo).

4.2.3 The effectiveness of Fortenza duo technology in controlling FAW in maize fields.

Farmers were asked whether they experienced FAW attack in their maize fields or not. The study found that more fortanza treated maize fields had no FAW attack as compared to hybrid and

local maize, both in treatment and control farmers. This implies that fortENZA duo helped in preventing FAW attack to maize. The study further found that fortENZA treated maize had lower attacks in the first weeks of plant germination for the treatment farmers than the non-treated hybrid and local varieties. The attack to fortENZA treated maize was also lower than the attack in hybrid and local maize varieties for control farmers. Therefore, fortENZA duo helped in delaying FAW attack to the maize. The study also found that FortENZA treated maize had substantially lower levels of infestation than the hybrids. The results meant that, fortENZA duo helped in reducing the severity of FAW infestation.

Using mixed regression analysis (with random effects for farmers) to determine if there was any statistical difference in the time when FAW attacked the maize. FortENZA treated maize variety was used as a control in this analysis. The study found that in hybrid maize varieties, FAW attacked 2.2 weeks earlier than in FortENZA treated maize plots. For local maize varieties the difference was slightly less, 1.8 weeks. These differences were highly significant, indicating that fortENZA duo delays the attack of FAW to the crops by over two weeks as compared to local varieties and untreated hybrids. From these results, fortENZA duo is effective in delaying FAW attack to maize. From the ordinal regression analysis, the study further found statistical significant differences in FAW severity among the varieties. The results showed a significant difference between FortENZA and the other varieties, indicating that the severity of attack was higher in the other varieties as compared to fortENZA treated variety. In other words, the results imply that FortENZA Duo reduces the severity of FAW infestation as compared to non-treated hybrids and local varieties. These results also imply that fortENZA duo is effective in controlling fall army worms in maize crop.

The study findings are in line with the studies and reports of other researchers on fortENZA duo and also on other similar seed treatment technologies which has been found to be effective. Troczka et al., 2017 reported that fortENZA duo has a broader spectrum of insecticidal activity and provides good control for the piercing and sucking insects for which fall army worms is included. Wilde et al. (2004) found that treating wheat seeds with Imidacloprid and Thiamethoxam was effective in controlling early season infestation of greenbug and Russian wheat aphid. Rice seed treatment with Chlorantraniliprole insecticide is effective in controlling rice water weevil (Michael, 2015). Silva et al (2016) carried out a greenhouse experiment to evaluate the effect of seed treatment in controlling fall armyworm in initial infestations of

soybean. Imidacloprid plus thiodicarb, thiamethoxam, chlorantraniliprole, cyantraniliprole (Fortenza 600 FS), fipronil plus pyraclostrobin and thiophanate-methyl, were the insecticides used for seed treatment. The insecticides; chlorantraniliprole and cyantraniliprole had the best results of greater efficacy will lower consumption of leaves by caterpillars. Seed treatment was again declared to be an effective way of controlling FAW at the start of crop development. Id et al. (2020) also reports that application of chlorantraniliprole and cyantraniliprole as seed treatment has a prolonged residual action and effective in controlling FAW. Adamczyk et al. (2014) found that treating soybean seeds with cyantraniliprole and chlorantraniliprole significantly lowered survival of fall armyworm larvae. The authors further stated that treating the seeds with these insecticides can reduce foliar sprays. A study by Conrad et al. (2016) investigated the impact of different insecticides sprayed in autumn or treated to winter oilseed rape seeds on cabbage stem flea beetles, aphids and virus infestation. In 2015, it was found that the effects of the seed treatment with Fortenza Force on larvae of cabbage stem flea beetle was limited, Fortenza Force treated plots had 0.4 fewer larvae than the control plots, and the adult beetles migrated into the field very late. This is similar to the delaying of fall army worms attack to maize when the maize seeds are treated with Fortenza Duo as found in this study. Rwomushana et al. (2018) also indicated that seed treatment is a possible way of using pesticides to control fall armyworms. The report indicates that treating the seeds with Fortenza Duo offers protection of the seedlings for up to 4 weeks and reduces foliar insecticide sprays for commercial farms by 1-3 times. Rwomushana et al. (2018) further indicated that seed treatment can be more useful if it can be complemented with insect resistant seed traits. The report however indicates that the efficacy of seed treatment may be affected by soil type due to differences in seed emergency, seeds in sand soils will germinate faster and benefit from the longer protection than the seeds planted in clay soil.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This research study was a contribution towards finding a solution to the problem of fall army worms. Fall army worms (FAW) is a *lepidopteran polyphagous* pest native to tropical and subtropical America, and is one of the most important pests of maize in Central America (Andrews, 1980) and Brazil (De-Almeida et al., 2002). It belongs to the genus *Spodoptera*, known as armyworms, the most destructive group of *Noctuidae* that give losses to agriculture produce worldwide (IITA, 2016). By the end of 2017, FAW was reported in Zambia and many sub-Saharan African countries (Day et al., 2017), threatening food security (Devi, 2018). The coming of FAW in Zambia has made the situation worse for the farmers, who already experience low crop productivity. If not controlled the FAW can wipe out the entire field of crops leading to total loss. Fortunate enough, Syngenta developed an insecticide called Fortenza duo, a seed coating insecticide which can protect crops from FAW attack. Fortenza duo has many traits and it can control about 28 crop pests. After application and planting, the insecticide is quickly taken up by the roots and moves upward in the plant through the xylem system, controlling ground and above ground insects. Before rolling out and encourage the farmers to adopt this technology in the country, it's important to carry out farmer evaluation of fortenza duo technology to assess its effectiveness, and that was the focus of this study. The objectives of the study were: To assess farmers' preference for Fortenza duo treated maize as compared to other maize varieties (hybrid and local varieties); to assess the socio-economic and environmental suitability of fortenza duo technology in controlling FAW in Zambia; and to evaluate the effectiveness of fortenza duo technology in controlling FAW in farmers' crop fields, as perceived by farmers, in Zambia. To achieve the objectives, the study used a survey approach to collect data from 153 treatment farmers and 162 control farmers. The study also had a survey of 35 treatment farmers, and also used a participatory survey and invited 202 farmers to evaluate the maize demonstration plots treated with fortenza duo technology. The study used descriptive and statistical analysis; ordinal regression and mixed regression analysis were used to analyze the data.

From the findings on the demonstration plots, farmers liked more the germination/crop stand, resistance to FAW and stalkborer, and bareness level of the fortanza treated maize. Farmers also gave high scores for height, grain size, and biomass, although for these criteria the scores were similar to the average overall score. The scores for yield, cob size, stalk thickness and number of cobs was lower than that for the overall evaluation. A subset of (35) treatment farmers scored fortanza treated varieties, SY6444 and SY5944, higher than hybrid and local varieties that were not treated. Local maize was scored lower than the mid-point (3) in terms of yield, grain size, cob size and number of cobs, and hybrid maize scored better than local maize. Using ordinal regression, the study found that for all criteria, farmers gave fortanza the highest score, and local or recycled varieties the lowest. Fortanza scored significantly higher than local or recycled varieties for all criteria. When comparing fortanza treated maize to the hybrids, the coefficients are only significant for Vigor (10%), Stalk thickness (1%), cob size (10%), grain size, and yield (5%). The study therefore concluded that fortanza treated maize was statistically more preferred than the hybrid and the local maize.

The study found that the farmer characteristics influencing FAW severity scores (0. Very low infestation, 1. Low infestation, 2. High infestation, 3. Very high infestation) is gender, experience, owning cattle and farmer type (treatment or control farmer). Been male a farmer is more likely to score low infestation of FAW. Farmers with more years of farming experience are more likely to score low infestation of FAW. Owning more cattle, a farmer is likely to score low infestation of FAW. Been a control farmer, a farmer is more likely to score high infestation of FAW.

Further, the study found that more fortanza treated maize fields had no FAW attack as compared to hybrid and local maize, both in treatment and control farmers. The study also found that fortanza treated maize had lower attacks in the first weeks of plant germination for the treatment farmers than the non-treated hybrid and local varieties. The study also found that Fortanza treated maize had substantially lower levels of infestation than the hybrids. The study found that the FAW will attack fortanza treated maize 2 weeks later than in untreated hybrid and local maize varieties. The study therefore concluded that fortanza duo is effective in controlling fall army worms in maize crop.

This study finding is in line with the reports of other authors, Troczka et al., 2017 reported that fortanza duo provides good control for the piercing and sucking insects including fall army

worms; Conrad et al. (2016) found that Fortenza force treated plots had 0.4 fewer larvae than the control plots, and the adult beetles migrated into the field very late. Rwomushana et al. (2018) report indicated that treating the seeds with Fortenza duo offers protection of the seedlings for up to 4 weeks and reduces foliar insecticide sprays for commercial farms by 1-3 times.

The study faced some limitations; the researchers were not engaged from the beginning of setting up the trials and demonstration plots, as well as in the selection of farmers who planted Fortenza treated maize, this led to the problem of not having a control to compare with the demonstration plots. However, the trial at Mount Makulu had a control, and the neighbors to the treated farmers (farmers who planted Fortenza treated maize) were interviewed as controls in the farmer survey. Despite the stated limitation, the study achieved all the set objectives, and gave the following recommendations.

5.2 Recommendations

1. Fortenza duo technology should be adopted by farmers in Zambia as a remedy for delaying fall army worm attack to maize, and reducing the FAW infestation in the maize crop.
2. Farmers should also be using FAW spray pesticides (e.g. Nimbecidine, Looper kill, Denim_Fit) in addition to planting Fortenza treated seeds, especially after 4 weeks of emergency, when they observe FAW in the fields.

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APPENDICES

Appendix 1: Farmer Evaluation Questionnaire

Introduction and Informed Consent

ENUMERATOR NAME: _____ **ENUMERATOR CODE:** _____

Good morning/Afternoon. My name is _____ I am coming from the University of Zambia. We are currently conducting farmer evaluation of different maize varieties. The primary goal of this evaluation is to understand farmers' appreciation of various traits as expressed by improved varieties.

This site has been randomly selected from sites where variety trials are taking place in Zambia and you the farmers from the area were invited to participate in this exercise. You were not selected for any specific reason and your participation is voluntary.

I would like to ask the questions from this form to you as a farmer. These questions will take about 60 minutes to complete. All of your answers will be held in confidence. The answers which you might give me will only be used by researchers from the University of Zambia and the International Maize and Wheat Improvement Centre (CIMMYT) or under their supervision.

Before I start, do you have any question or is there anything that I have said for which you would like further clarifications? May I proceed with interviewing you? ____Yes ____No
_____Initials.

Should you have any question or concern, please contact Dr. Chewe Nkonde (+260973489931) or Dr. Hugo De Groot (0722595165).

RESPONDENT IDENTIFICATION AND CHARACTERISTICS

Date of the evaluation: _____/_____/_____

District/ _____ Constituency _____

Ward _____ Village _____

Participant's name _____

Mobile number _____

Gender of the participant Male=1, female =2

Age: _____(years), Experience in farming _____

Years of formal education: _____

Highest level of education attained _____

(Lower primary =1, Upper primary school =2, lower secondary =3, upper secondary =4, Tertiary =5)

Size of the farm: Quantity _____ unit

Area under maize: Quantity _____ unit.....

Did you purchase improved maize seed this season? Yes/ =1, No=0

If yes which were the three major certified maize variety planted (be specific)

MZVAR1 _____

MZVAR2 _____

MZVAR3 _____

Did you use fertilizer in your maize field this season___?

Yes =1, No =0

Number of cattle owned _____? How many oxen _____?

Do you use oxen to plough your farm? (0 = No, 1 = Yes) _____

Category/type of participant: (check one)

Respondents category	Tick one/
Farmer who hosts the trial	
Invited farmer	
Extension officer	
Syngenta staff	
Administration officer	
Other participant: _____	

FAMER KNOWLEDGE ON FAW ARMY WORMS AND CONTROL MEASURES

17. Are you aware of faw army worm attack to maize and other crops? 1.Yes [] 2. No []

18. Have you ever experienced faw army worm attack in your maize field? 1. Yes [] 2. No []

19. If yes,

a) what was the first year you observed it?

b) did you use any pesticide/technology in controlling for the faw army worms in your maize field?

Yes [] 2. No []

20. If yes, what pesticide/technology did you use to control for the faw army worms in your maize field?

No. field	After germination, how long (in weeks) did it take you to observe FAW in this field? # of weeks	What FAW and pest control measures did you use for the plot	how severe was the FAW infestation in this field? (0=very high infestation; 1=high infestation; 2=low infestation;3=very low infestation	Number of treatments	Area treated		Cost per treatment		Effectiveness	Comments
					Area size	Unit	Cost of technology	Labor (Hours)		
1										
2										
3										
4										
5										

For effectiveness use this key: 1. Very ineffective; 2. Ineffective; 3. Neither effective or ineffective; 4. Effective; 5. Very effective

21. How many 50Kg bags of maize did you harvest/expecting to harvestbags

22. How many 50Kg bags have you lost/expecting to loose due to faw army wormsbags

23. Indicate the level to which the following criteria are important to you in choosing a pesticide technology.

How Important is this pesticide criteria? (0=not important, 1 = low importance, 2 = medium, 3 = very important)		
	CRITERIA	
i	odor	
ii	cost	
iii	Labor requirement	
iv	Health risk	
v	Effectiveness	
vi	Technology embedded in the seed	
vii	Convenient (easy to use)	

How Important is this criteria?		Indicate the likeness of each plot for the criteria listed A = like very much, B= like, C= neither like nor dislike, D= dislike E= dislike very much										
Criteria	How Important is this criteria? (0=not important, 1 = low importance, 2 = medium, 3 = very important)	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5		Plot 6	Plot 7	Plot 8	Plot 9	Plot 10
Germination/Crop stand												
Height/												
Stalk thickness/												
Number of cobs per plant												
Cob size												
Barrenness level/												
Grain size												
Yield												
Biomass (for fodder)/												
Resistance to stalk borer/												
Resistance to faw army worm												
Grain weight												
Drought resistance												

Foliar disease resistant													
Early maturing/													
Overall evaluation (note: not an average)/													

THANK YOU FOR YOUR PARTICIPATION

Appendix 2: Farmer Survey Questionnaire

QUESTIONNAIRE

PART I

Introduction and Informed Consent

ENUMERATOR NAME: _____ *ENUMERATOR CODE:* _____

Good morning/Afternoon. My name is _____ I am coming from the University of Zambia. We are currently conducting farmer evaluation of different maize varieties. The primary goal of this evaluation is to understand farmers' appreciation of various traits as expressed by improved varieties.

This site has been randomly selected from sites where variety trials are taking place in Zambia, and you and selected farmers from this area were invited to participate in this exercise. You were not selected for any specific reason and your participation is voluntary.

I would like to ask the questions from this form to you as farmer. These questions will take about 60 minutes to complete. All of your answers will be held in confidence. The answers which you might give me will only be used by researchers from the University of Zambia and the International Maize and Wheat Improvement Centre (CIMMYT) or under their supervision.

Before I start, do you have any question or is there anything that I have said for which you would like further clarifications? May I proceed with interviewing you? ____ Yes ____ No
_____ Initials

Should you have any question or concern, please contact Dr. Chewe Nkonde (+260973489931) or Dr. Hugo De Groote (+254722595165).

RESPONDENT IDENTIFICATION AND CHARACTERISTICS

Date of the evaluation: _____/_____/_____

District: _____ Ward: _____

Camp: _____ Village: _____

Enumerator Name: _____

GPS Latitude

Longitude

Participant's First Name _____ Last Name _____

Mobile number _____

Gender of the participant Male=1, female =2

Age: _____ (years)

Experience in farming (years) _____

Highest level of education attained _____

(Lower primary =1, Upper primary school =2, Lower secondary =3, Upper secondary = 4 Tertiary =5)

Size of the farm: _____ (quantity) _____ (units: ha, acres, m2. ...)

Total land under cultivation: _____ Quantity _____ Units _____

Area under maize production: _____ Quantity _____ Units _____

Number of cattle owned _____? How many oxen _____?

Do you use oxen to plough your farm? (1 = No, 2 = Yes) _____

Category/type of participant: (check one)

Cash household income last 12 months? - use the table below to compute

Household income sources	Amount (ZMK)
Crop sales income	
Livestock sales income	
Livestock products sales income	
salary and wages income	
Income from businesses	
Remittances, Pensions and transfers income	
Total	

SECTION B. MAIZE PRODUCTION

Field ID	<u>Enumerator:</u> What is the area of this field?		What maize variety was grown in this field in 2018/19 season? See codes below	What was the total area planted?		What was the cost of land preparation and planting associated with this plot?	What quantity of seed did you plant?		What was the cost seed planted?	Did you apply any fertilizers?	What weed control measure did you use		Pest control	
	Area of field	Unit <i>1=lima 2=acre 3=ha</i>		Area of field	Unit <i>1=lima 2=acre 3=ha</i>		Quantity	Unit <i>(see codes below)</i>			If yes Compound D Urea Animal manure	What was the cost associated with the fertilization and its application? ZMW	Herbicides (name them Manual/ hand hoe mechanical	What was the cost associated with the use of this measure? ZMW
Plot 1			Fortenza DUO coated seed											
Plot 2														

SECTION C: HARVESTING

Field ID	What maize variety was grown in this field in 2018/19 season? See codes below	What quantity of crop did you harvest from this field?		How much was lost due to FAW?		How do you expect to sale your crop at?	
		Quantity	Unit	Quantity	Unit <i>(see codes below)</i>	Quantity	Unit
Plot 1	Fortenza DUO coated seed						
Plot 2							
Plot 3							
Plot 4							

SECTION D: COSTS AND BENEFITS OF FORTENZA TECHNOLOGY

21. How would you rate a price of ZMK for accessing fortenza duo technology in controlling faw army worms.

Very affordable []

- Affordable []
Neither []
Unaffordable []
Very unaffordable []

22. How would you compare the cost of fortanza duo technology to the costs of using other technologies? The cost of fortanza duo technology is;

- Very fair []
Fair []
Neither []
Unfair []
Very unfair []

23. In the first 4 weeks of germination which of the technologies is more efficient in controlling faw army worms?

- Fortanza duo technology []
Existing spray technologies []

THANK YOU FOR YOUR PARTICIPATION

Appendix 3: Sub Sample Survey Questionnaire

Farmer Evaluation and Economic Analysis of Fortenza Duo in Controlling Fall Army Worm Follow-up Survey

Name of farmer:

Province:

District:

Camp:

Village:

Enumerator:

Date of interview:

Dear Farmer,

We have a few questions that we would like to ask you as a follow up to the survey that we conducted in July and August, 2019. This is a collaborative study that is being undertaken by Syngenta, the International Maize and Wheat Improvement Centre (CIMMYT) and the University of Zambia. Please take note that the reference agricultural season we are focusing on is the 2018/19 season and not the current season (2019/20) that commenced on 1st October 2019.

Section A

What maize variety did you plant in this field during the reference agricultural season?

Maize variety: a. Fortenza b. Hybrid c. Local maize

What quantity of this maize seed variety did you plant in this field during the reference agricultural season?

What was the size of the field in which this maize seed variety was planted during the reference agricultural season? (record the farmer's own measurement)

We would like to physically measure the field, should we go ahead?

Yes

No

Enumerator, please record the size of the field after your physical measurement.

What land preparation method did you use in this field?

How many seeds of this variety were you planting per station?

When did you plant this variety?

What was the quantity of this maize variety that you harvested from this field?

For this variety and field, you indicated that your yield was _____, which is less than 40*50kg shelled maize per lima. Why was your maize yield low?

Section B

Indicate farmers' likeness of the following maize criteria for Fortenza and Their own Fields

A = like very much, B= like, C= neither like nor dislike, D= dislike E= dislike very much

	Fortenza Plot	Farmers Field
Germination		
Stalk thickness/		
Number of cobs per plant		
Cob size		
Grain size		
Yield		
7. Overall evaluation		

Appendix 4: Breusch and Pagan Lagrangian multiplier test for random effects.

	Var	sd = sqrt(Var)
Time of FAW_Attack	5.392405	2.322155
e	4.31007	2.076071
u	0	0

Test: $\text{Var}(u) = 0$

chibar2(01) = 0.00
Prob > chibar2 = 1.00

H0: The model residuals do not contain individual specific error components.