NAMIBIA UNIVERSITY
OF SCIENCE AND TECHNOLOGY

THE IMPACT OF 2016/17 FALL ARMYWORM OUTBREAK ON PEARL MILLET YIELD IN NAMIBIA

by

Lynnety Chaze Sinalumbu

Thesis submitted to the Namibia University of Science and Technology in partial fulfilment of the requirements for the degree of Master of Agribusiness Management

Windhoek

Namibia

Supervisor: Mr Teofilus Shiimi

FACULTY OF HEALTH, NATURAL RESOURCES AND APPLIED SCIENCES

DEPARTMENT OF AGRICULTURAL SCIENCES AND AGRIBUSINESS

NAMIBIA UNIVERSITY OF SCIENCE AND TECHNOLOGY

Co-Supervisor: Dr Thinah Moyo

FACULTY OF HEALTH, NATURAL RESOURCES AND APPLIED SCIENCES

DEPARTMENT OF AGRICULTURAL SCIENCES AND AGRIBUSINESS

NAMIBIA UNIVERSITY OF SCIENCE AND TECHNOLOGY

February 2023

Declaration

I, Lynnety Chaze Sinalumbu, hereby declare that the work contained in the thesis titled, "Investigating Direct Economic Impact Caused by Fall Armyworm Outbreak in Namibia During 2016/2017 Season," is my original work and that I have never submitted it in its entirety or in part at any university or higher education institution for the award of a degree.

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Table of Contents

Declaration ii

Retention and Use of Thesis iii

Table of Contents iv

List of Figures vi

List of Acronyms vii

Acknowledgements viii

Dedication ix

Abstract x

Chapter 1: Introduction 1

1.1 Background 1

1.2 Problem statement 2

1.3 Research objectives 3

1.3.1 Overall objective of the study 3

1.3.2 Specific objectives 3

1.4 Research hypotheses 4

1.5 Justification of the study 4

1.6 Thesis outline 4

Chapter 2: Literature Review 6

2.1 Introduction 6

2.2 Review of FAW outbreak 6

2.2.1 Description of FAW 6

2.2.2 Distribution and spread of FAW 8

2.2.3 Effect of FAW on maize yield in Ghana and Zambia 9

2.2.4 Field infestation levels in Ghana and Zambia 9

2.2.5 Yield loss estimation due to FAW in Ghana and Zambia 9

2.2.6 FAW outbreak in Asia 10

2.2.7 FAW outbreak in Europe 10

2.2.8 FAW outbreak in Africa 11

2.2.10 Gender differences in FAW control in Ghana and Zambia 13

2.2.11 Effects of FAW outbreak in Namibia 13

2.2.12 Economic impact of FAW outbreak on pearl millet output 13

2.2.13 FAW strategies used by farmers to control the outbreak 15

2.3 Summary 16

Chapter 3: Methodology 17

3.1 Introduction ... 17
3.2 Study area ... 17
3.3 Research design ... 18
3.3.1 Quantitative research design ... 18
3.4 Sampling ... 19
3.5 Data collection ... 19
3.6 Data analysis ... 19
3.6.1 ANOVA ... 20
3.6.2 Chi-squared tests ... 22
3.6.3 Descriptive Statistics ... 24
3.7 Summary ... 25
Chapter 4: Results and Discussion ... 27
4.1 Introduction ... 27
4.2 The characteristic of the respondents ... 27
4.2.2 Household head gender ... 28
4.2.3 Age distribution ... 29
4.2.5.5 Severity of FAW on the farmer's crop yield and livelihood ... 36
4.2.5.6 Strategies and methods used to control FAW outbreak ... 37
4.3 Hypotheses testing ... 39
4.4 Summary ... 39
Chapter 5: Conclusion and Recommendations ... 40
5.1 Introduction ... 40
5.2 Conclusions ... 40
5.3 Recommendations ... 41
5.4 Recommendations for future research ... 42
References ... 43
Appendices ... 47
Appendix 1: Field Sheet for Data Collection ... 47
Appendix 2: Anova Tables ... 52
Appendix 3: Certificate of editing ... 54

List of Figures

Figure 1: FAW detected in Kavango East region 8
Figure 2: Leaf damage by FAW in Kavango East region 12
Figure 4: Study area 17
Figure 5: Regional Constituencies 27
Figure 6: Gender of farmers 29
Figure 7: Age group of farmers 30
Figure 8: Education of farmers 31
Figure 9: Expected and actual yield difference over three seasons of pearl millet 32
Figure 10: Difference between expected & actual yield per season of pearl millet 33
Figure 11: Actual yield difference over three seasons 35
Figure 12: Severity of FAW outbreak over three seasons 36
Figure 13: Control methods used to control the FAW outbreak over three seasons 37
Figure 3: Trained technical staff member from the MAWLR 39

List of Acronyms

ADCs	-	Agricultural Development Centres
AMTA	-	Agricultural Marketing and Trade Agency
ANOVA	-	Analysis of Variance
ATs	-	Agricultural Technicians
DFID	-	Department for International Development
FAO	-	Food and Agriculture Organization of the United Nations
FAW	-	Fall Armyworm
IPM	-	Integrated Pest Management
MAWF	-	Ministry of Agriculture, Water and Forestry
MAWLR	-	Ministry of Agriculture, Water and Land Reform
MS	-	Mean Squares
NCA	-	Namibia Census of Agriculture
NSA	-	Namibia Statistics Agency
PSU	-	Primary Sampling Units
SADC	-	Southern Africa Development Community

Acknowledgements

First, I want to express my profound gratitude to my supervisor, Mr. Teofilus Shiimi, for his helpful guidance and counsel given to me when I was writing this thesis.

Second, I want to express my gratitude to my co-supervisor, Dr. Thinah Moyo, for her support during the entire process. Without her help, this thesis would not have been feasible.

Thirdly, I want to express my deep gratitude to my Ministry of Agriculture, Water, and Land Reform co-workers for their support and generosity during the data gathering phase. A special thank you to the Department of Agricultural Science and Agribusiness (DASA) and the Faculty of Health, Natural Resources and Applied Sciences (FHNRAS) at the Namibia University of Science and Technology for giving me the chance to expand my knowledge through this institution. The entire personnel of the Faculty and Department will not go unappreciated for the help and encouragement they have given me; after all, they were the key factors in this thesis' achievement.

I also like to sincerely thank the farmers and producers that contributed to this thesis for the helpful data they gave throughout data collection, which was essential to its success. Without their useful contributions, this thesis would not have been conceivable.

I want to thank my family and friends for their constant support and assistance with my thesis. I want to express my sincere gratitude to each one of them for their support, devotion, and encouragement in helping me pursue my thesis with fervour and commitment to its completion.

Finally, I want to express my gratitude to the Almighty Lord for enabling my job. His love had enabled me to receive his care and protection and to be strong enough to overcome all the difficulties I ran through while writing this thesis.

Dedication

I would want to dedicate this work to my son, Tichawona Daniel Mapolisa, as well as to everyone who has given me support or guidance while I have been studying.

Abstract

Two-thirds of the population in Namibia live in rural areas of which the majority depends on smallholder crop production as means of livelihoods. The main staple food and income generating crop grown in the North and North-Eastern regions of Namibia including Kavango East region is pearl millet. Assessments conducted between mid-February and the end of April 2017 showed that approximately 356,000 hectares of crops were affected by the Fall Army Worms (FAW) infestation in seven reported Southern African Development Community (SADC) member states including Namibia. This study examined the pearl millet yield impact caused of FAW outbreak on crop harvest during 2016/2017 cropping season in Kavango East region in Namibia. The data was collected from 100 farmers from Kavango East region. ANOVA model was applied to find the significant difference between expected and actual yield of pearl millet across the three year growing-seasons. The same model was used to analyse the differences between expected and actual yields of pearl millet between growing seasons. Chi-square test was used to determine the severity of FAW outbreak on the livelihoods of farmers. Descriptive statistic was used to determine the mitigation method used by farmers to lessen the impact of the FAW. The Welch's *t*-test indicates that there is a highly statistically significant ($p<.0000115$) difference between the expected and actual yield over three years. The second test revealed that there is a statistically significant difference $p<.0000114$ and $p<.02$ respectively in terms of expected and actual yield in the 2017 and 2018 cropping seasons and no statistically significant difference in 2019 cropping season. The analysis of severity of FAW in the livelihood of farmers in terms of loss of income with chi-square test indicates that there is a statistical significance difference amongst farmers who experienced the outbreak and those who did not with $P<.1.98e-72$ prompting the study to reject the null hypothesis. Evidence from the study indicates that the tactics/methods adopted to contain the FAW outbreak differ significantly from one another. The findings also indicated that the FAW outbreak influenced the production of pearl millet, which influenced the yield and way of lives of farmers who heavily relied on pearl millet as a staple diet. The study recommends that Namibia's Ministry of Agriculture, Water, and Land Reform inform farmers about low-cost pest control methods and urge them to diversify their cropping by thinking about other cash crops that are not or less affected by FAW. It is suggested that the aforementioned ministry create a strategy to deal with the FAW epidemics in Namibia.

Keywords: *Fall Armyworm, income, livelihood, pearl millet, production, yield, strategy.*

Chapter 1: Introduction

1.1 Background

The Namibia Statistics Agency (NSA) alludes that nearly two-thirds of the population in Namibia live in rural areas, and the majority depend on smallholder crop production as main source of livelihood (Namibia Statistics Agency (NSA, 2015). However, their livelihoods are influenced by various factors such as low level of education, culture and tradition, poverty, religious beliefs, politics, environmental factors such as drought, flood and pests (NSA, 2015).

The total human population of Namibia has been projected to increase from the present 2.2 million with majority located in the central-north and north-eastern regions namely Omusati, Oshana, Ohangwena, Oshikoto, Kavango East, Kavango West and Zambezi. Kavango East population alone stood at 136 823 (NSA, 2015). Kavango East rural communities are predominantly agriculturists whose livelihood is dependent on farming and fishing. According to Thiem and Jones (2014), most of the region's inhabitants are engaged in some form of agricultural production, primarily small-scale mixed farming of mahangu (pearl millet) and rearing of small numbers of goats and cattle. Cattle and poultry are the most important assets in terms of livestock (NSA, 2015). Fishing is another aspect of livelihood for the rural communities living close to the Kavango River (Brown, 2010). As of recent, the mahangu and maize production has been affected by pests such as locusts, termites, aphids and FAW just to mention a few that has negative impact on the livelihood of the local communities.

The FAW is an insect that consumes more than 80 plant species, including cotton, sugarcane, cottonseed, rice, sorghum, pearl millet, and maize. Given the correct environmental factors, it may quickly multiply and spread and has a voracious appetite (Hay-Roe, Meagher, Mura, Nagoshi, Santos, Vilardi, 2019). The food and nutritional security of millions of farming households in Africa is hampered by this insect originating from the tropics of North and South America (Day, Lamontagne-Godwin, Silvestri, Beseh, Oppong-Mensah, Phiri, & Matimelo et al., 2020). The pest can have multiple generations in a single year due to the favourable climate found in many areas of tropical Africa and the number of suitable host plants (Ordóñez-García et al., 2015). FAW, as opposed to other armyworms that are migratory, has turned into a persistent pest in African farming systems (Oliveira et al., 2018). More than 40 African countries reported FAW by February 2018 (Kassie, et al., 2018). The untouched nations of Africa, which are mostly in North Africa, continue to be at high danger and could provide as a pathway for the pest to go to Europe's Mediterranean region (Abrahams, Beale, Bateman, Clottey, Cock, 2017; Day, Khan, Midega, Nagoshi et al., 2017; Pickett, 2018, & Pittcha). FAW outbreaks can cause severe damage in maize and other crops if they are not controlled, especially in the absence of natural biological control (Castillo, Cruz-Lopez, De La Rosa-Cancino, Malo, & Rojas, 2016). When calculating the probable yield loss due to FAW infestation, there are numerous factors to consider (Kumela et al., 2019). In general, the population size and the nutritional and moisture state of the maize plant have a significant impact on how the FAW infestation is handled (Aguirre et al., 2016). In fact, there have already been cases of FAW being discovered in cut flowers coming from East Africa (Nagoshi, 2019). Emergency measures in some FAW-affected nations in Africa have mostly relied on the use of synthetic/chemical insecticides (Jacobs, Rong, & Vuuren, 2018). As part of the emergency response to FAW, millions of dollars were spent on the purchase and distribution of pesticides, some of which are highly toxic or hazardous. This is not only unsustainable in the long run but is also certain to be extremely harmful to human health, biodiversity, and the environment. It also led to an unsustainable "pesticide treadmill" (Prasanna et al., 2018). Therefore, it is crucial to discourage the use of extremely risky insecticides against FAW and instead advocate for and implement available, dependable, and tested technologies as part of the integration of pest management (Prasanna et al., 2018). To give information and suggest potential actions that can be considered for the smallholder sector to provide the nation with enough grain output, this study set out to analyse the 2016/17 impact caused by the FAW outbreak on farmer' pearl millet yields.

1.2 Problem statement

In the Kavango, Ohangwena, Omusati, Oshikoto, Otjozondjupa, and Zambezi areas, armyworms infected 50,000 hectares of maize and pearl millet crops and 20,700 households (Food and Agriculture Organization of the United Nations (FAO), 2018). Cereal crop production is considered as a sustainable practice of producing food and income generating activity for small-holder farmers. Production of cereal crops has been a challenge in Kavango East, even though some technical and financial support has been provided by the MAWLR including their key stakeholders.

Uncertainty over the usefulness of smallholder grain farmers as a tool for increasing the nation's grain base has undoubtedly resulted from such a case of low grain (pearl millet) levels by smallholder farmers.

Cereal producers have not totally reaped the profits from farming because of these low yields. The nation's overall basis for cereal production has been impacted by this. Pest infestation is one of the issues smallholder cereal farmers confront, according to the FAO (2018), and it has an impact on their ability to generate income. It is estimated that between 80% and 90% of the harvest was lost due to the FAW outbreak in Kavango East region (FAO, 2018).

The FAW are pests that are well-known and bothersome (MAWF, 2017). After it began to spread across farmers' fields, crop losses were noticed, which resulted in low agricultural harvests (Fermont & Benson, 2011). FAW outbreaks are frequently to blame for low, inconsistent output levels and diminishing agricultural yields (Anderson, Fermont & Benson, 2011; Harris-Shultz, Knoll, & Ni, 2015). A 2017 report from the UN Office for the Coordination of Humanitarian Affairs (UNOCHA) states that Namibia imported a significant amount of cereal in 2016 to feed more than 50% of the country's people. Due to the fact that the majority of households who might have harvested during the 2016–2017 season apparently exhausted their meager harvests, they were forced to rely on the retail market and the government's drought relief food program to obtain food. The report, however, revealed that the amount of domestically produced cereal that was currently available was only about 52% of what was needed for domestic consumption. As a result, 21 400 tons of pearl millet were needed to make up the total deficit of 167 000 tons, which included maize and sorghum.

1.3 Research objectives

1.3.1 Overall objective of the study

The overall objective of the study is to determine the impact of 2016/17 FAW outbreak on farmer' pearl millet yields in Kavango East region in Namibia. In order to attain the main overall objective of the study the following specific objectives were pursued.

1.3.2 Specific objectives

- To determine the expected and actual yields of pearl millet output;
- To determine the severity impact of FAW outbreak on the farmers' crop yields and livelihoods; and
- To identify strategies used by farmers to control the FAW outbreaks.

1.4 Research hypotheses

The objectives were attained by testing the following hypotheses:

H_0: There is no statistically significant difference in expected and actual yields of pearl millet among farmers who experienced the FAW outbreaks.

H_0: There is no statistically significant difference in the severity of farmer' livelihoods who experienced FAW outbreaks.

H_0: There is no effectiveness in different strategies used in maintaining output level when FAW outbreaks occurred.

1.5 Justification of the study

With the increasing effects and threats due to climate change, it is crucial to investigate different kinds of pests that can be controlled using pesticide and other natural biological control measures to adapt to adverse climatic conditions. This study was motivated by possibility of FAW outbreaks during the past years, hence there is a need to understand the socioeconomic factors that can influence farmer's management capabilities for efficient productivity and Integrated Pest Management (IPM) systems, as these are useful for policy formulation and decision making by governments.

This study informs farmers in Kavango East region on what to do to mitigate the economic impacts caused by the FAW outbreaks in the agricultural sector. Additionally, the study informs the academic on areas that still need more research to be conducted in future. Finally, the study also informs the society at large on what types of appropriate strategies can be applied at grass root levels to address the challenges faced by farmers during the said outbreaks.

1.6 Thesis outline

This thesis consists of 5 chapters. Chapter 1 provides the background of the study, which details the problem statement and outlines the research objectives and hypotheses. Chapter 2 reviews the published literature related to the study as secondary research. Chapter 3 describes, explain, and justifies the research approach and research methodologies used in the study. Chapter 4 presents the results of the data collected and analysed. Chapter 5 concludes the study and gives recommendations for future actions.

Chapter 2: Literature Review

2.1 Introduction

This chapter reviews scholarly articles, books, and other sources relevant to the study. The chapter also provides a description, summary and critical evaluation of each source and identifies gaps in the literature areas which need further research. In so doing, the chapter provides historical background of the research, describes issues, theories, concepts, and related research in the field; and shows how the research extends these or addresses a gaps.

2.2 Review of FAW outbreak

2.2.1 Description of FAW

This FAW invasive pest was first discovered in Africa in early 2016 in the rainforest regions of Central and Western Africa (Early et al., 2018). It is a native of the tropical regions of North and South America. The pest can produce multiple generations in a single year due to the favourable climate found in many areas of tropical Africa and the number of good host plants (Ordóez-Garca et al., 2015).

FAW feeds on different species of plants on leaves, stems, and reproductive parts. According to a study by Casmuz et al. (2010), there are up to 186 FAW host plants in America, which are attacked by 42 different families of FAW. Another review study by Montezano et al. (2018) in America found that figures are high up to 353 host plant species that are attacked by FAW pests. Additional surveys in Brazil have revealed 76 plant families that are attacked by FAW, and these include poaceae, asteraceae and fabaceae. As for Africa, the most affected crop by FAW in Ghana and Zambia is the maize crop followed by sorghum, pearl millet, napier grass and tomatoes. FAW larvae feed on the foliage of plants like maize, sorghum, and millet, and can affect plants throughout the entire growing season. "Large FAW infestations plants generally occur along levees, field boarders, and in parts of the field where larvae can escape the flood and can consume high amounts of tissue" (McCullars, 2019). Plant leaves are skeletonized by larvae during their first three instars; the first instar hardly ever completely consumes a leaf. Whole plants can become defoliated by fourth to sixth star larvae (Capinera, 2018).

FAW has been observed in several African countries as non-seasonal where host plants are perennial under irrigated crops. In such areas, high population of FAW is more likely to build up and the main season crops is more highly susceptible to infestation earlier. In cases of cooler climatic conditions in America, FAW populations usually die out, but the migrating moths cause the damage. The patterns of population presence, dispersion, and migration show that FAW exist in crop fields and endure throughout the year in regions of bimodal rainfall pattern in Africa. Crops in some areas where FAW does not persist year-round are impacted by FAW migration from established populations. Studies in Africa have not yet provided clarification on the two scenarios for FAW migration using different methods (Prasanna et al., 2018).

FAW egg masses can range in size from 100 to 200 eggs, with a female generating up to 1,500 eggs at a time and a maximum of nearly 2000 eggs throughout the course of her adult life. Approximately 6–7 times during 28–30 days, FAW can lay eggs. Scale deposits in and around the eggs give them a mouldy appearance once eggs are adhered to greenery. In the summer, eggs hatch in two to three days (Capinera, 2008). Moths are a group of insects with a life cycle of 10 to 21 days that are all Lepidoptera but are not butterflies (Nagoshi et al., 2017). Masses of dome-shaped eggs with flat bases that curve upward to a rounded point at the apex are laid by the female moth. The eggs have a diameter of around 0.4 mm and a height of about 0.3 mm (Jeger et al., 2017). First and second instars of FAW are often greenish with a black head and have a granular texture, according to Capinera (2008). The six instars of the FAW can be distinguished by the inverted "Y" on its head. The Fall Armyworm grows from a first instar length of 1.7 mm to a sixth instar length of 34.2mm. Night-time being the larvae, which travel down the canopy for darker circumstances since they are nocturnal, do so during the brighter parts of the day.

During the summer, the larval stage lasts roughly 14 days (Regan et al., 2018). Larvae of the Fall Armyworm pupate in a dirt cocoon between 2 and 8 cm deep. The oval-shaped cocoon measures 20 to 30 mm in length and is made of dirt and silk. The pupae are roughly 14 to 18 mm length and 4.5 mm wide, and they have a reddish-brown appearance.

In the summer, the pupal stage lasts for around 8 to 9 days, whereas in the winter, it can last for up to 30 days (Chinwada, 2018). Wingspans of adult FAW range from 32 to 40 mm. Male FAW moths have more pronounced white, triangular patches near the tip and in the middle of the forewing than do female FAW moths. Both sexes' rear wings have a bordered, iridescent silver-white look. Adults are nocturnal and most active in the warm, muggy evenings. They have an average lifespan of around 10 days, although they can live up to 21 days. Normally, the adult female lays her eggs five days following eclosion (Luginbill, 1928).

Figure 1: FAW detected in Kavango East region

Source: MAWLR, 2020

2.2.2 Distribution and spread of FAW

Twenty eight African nations are reportedly affected by FAW, and additional nations were confirmed in a 2017 evidence note by the Ministry of Agriculture, Water, and Land Reform. As of September 2018, 44 countries in Sub-Saharan Africa had been invaded as FAW spread. Publications were verified by several sources, including official IPPC reports, articles published in peer-reviewed journals, ministerial statements, and UN linked organizations. Additionally, FAW migrated from the main African continent to Madagascar and the Islands (Chinwada, 2018).

Strong flight capability is the primary factor causing FAW to spread quickly in Africa, and when it is discovered in one nation, it frequently has already moved to numerous neighbouring countries (Cock et al., 2017). Prior to invading Africa, FAW was discovered in Europe. According to Directive 2000/29/EC, FAW should be totally eradicated. FAW is categorized as a "Union quarantine pest" in Africa (Jeger et al., 2017).

2.2.3 Effect of FAW on maize yield in Ghana and Zambia

During 2017/18 Ghana and Zambia witnessed a dry season that impacted on the yield resulting in low maize production levels at various maize regions in Zambia. Farmers in Zambia still believe that the outbreak of FAW was one of the drivers of change in maize yield, on par, and farmers expected much higher maize yields if it was not the impact of FAW in the still in the absence of the outbreak of FAW, in the 2016/17 of favourable rain. This was revealed in a survey to determine the farmers' perceptions on the impact of FAW and drought in Zambia (FAO, 2018c).

The outbreak of FAW in Ghana was reported by 37% of farmers in 2016, 58% in 2017, and only 5% in 2018 indicating the effect of intervention response in 2018. Maize yield losses were low with good harvest in 2016 in Ghana but was more significant in 2017 (USDA FAS, 2018). Despite reduced yields due to FAW infestation in 2017, the subsidized government fertilizer programme helped to maintain favourable yields since more farmers used fertilizer (FAO, 2018d).

2.2.4 Field infestation levels in Ghana and Zambia

By sampling 100 plants from between 17 and 300 farmers who had maize crops in their fields, the levels of field infestation in Ghana and Zambia were determined. Most farmers in both countries were able to distinguish between damage from FAW and damage from maize pests (97.2% in Ghana and 89.9% in Zambia). According to the poll, 38% of farmers in Ghana and 18% of farmers in Zambia could tell the difference between FAW damage and other maize pest damage on afflicted plants. About ten percent of farmers in Zambia and 19% of farmers in Ghana reported finding FAW larvae. Compared to other crops, maize was shown to be the most damaged crop in both countries. In addition to maize, other cereals, and grasses, such as napier grass, sorghum, and pearl millet, have also been reported to be FAW impacted (Chapoto et al., 2017).

2.2.5 Yield loss estimation due to FAW in Ghana and Zambia

Yield loss estimation due to FAW in Zambia was done through a survey that involved asking farmers to give an estimate of their current production and the prediction of expected yield in the absence of FAW comparing previous yields and expected current for the year 2017 (Jeger et al., 2017). The estimate of average yield loss due to FAW was expressed as a percent of the difference between actual and expected production value. The results of the survey revealed an estimated average yield loss of 97% in Ghana and 99% in Zambia (FAO, 2018[b]). Comparing the yield from the impacted farmers and the non-affected farmers in the same area was done as a second alternative way of yield loss calculation (FAO, 2018[b]). The recall approach was used to compare the variations in estimated yield loss across all Agro-ecological zones (Cock et al., 2017). Results showed that farmers in Ghana and Zambia experienced a yield loss due to FAW ranging from 26% to 35% (Chinwada, 2018). A similar study was done for Namibia to determine the yield losses on maize, sorghum, and pearl millet caused by the FAW outbreak. Overall, the communal sub-impacted sector's farmers lost 13 percent of their maize yield, resulting in an eight percent loss in the communal sub-overall sector's maize production on a national level. Based on early Government output forecasts, this would result in a 277 tonnes decrease in total maize production. The proportionate yield loss calculated using farmers' recall and forecast would have been equivalent to 57 percent in comparison to these findings, indicating that the impacted farmers most likely considerably overestimated their yield loss. The projected yield loss of the impacted farmers for pearl millet was 14 percent, which equates to a proportional production of 6 percent of the national potential millet production or a total loss in millet production of 3 972 tonnes. Last but not least, it was calculated that affected farmers' yield losses for sorghum were 19 percent. Given the low rate of infestation in sorghum, this would result in a proportional output loss of 2% of the potential sorghum production at the national level, or a total production loss of 62 tonnes (FAO, 2018[b]).

2.2.6 FAW outbreak in Asia

Early in 2018, FAW broke out in Asia, and in July 2018, reports of it in Yemen and India (Ganige et al., 2018; Sharanabasappa et al., 2018). Three explanations for the spread of the disease from Africa across the Indian Ocean to Asian nations have been proposed: natural migration, wind-assisted migration from Africa to South Asia via the southwest monsoon winds, and finally, stowaways or contaminants on goods and planes traveling from Africa to Asia (Anderson, 2009; Regan et al., 2018).

2.2.7 FAW outbreak in Europe

Earlier than in Africa, FAW was found in Europe. The European Food Security assessment, which focused on sweet corn and other commodities, discovered that FAW was commonly detected in shipments from

America (Jeger et al., 2017). Tens of thousands to more than a million individual larvae could have been transported to the EU annually on commodities, according to the assessment's predictions (Jeger et al., 2017). The main host of FAW in the EU was discovered to be sweetcorn, and actions to reduce risk there were found to be 100 times more effective in preventing entry through imports (Jeger et al., 2017).

2.2.8 FAW outbreak in Africa

The FAW invasion was the most recent shock or stressor to hit Africa in 2016. It endangered the security of the food supply in many African countries, including Namibia. Therefore, FAW infestation resulted in smallholder farmers in other parts of the country that were affected by the outbreak losing their ability to feed themselves and maintain their way of life (FAO, 2017).

Namibia Census of Agriculture (NCA) (2013) states that for the communal sector survey, a stratified two-stage cluster sample design was used, and primary sampling units (PSU) were chosen with probability proportional to size (PPS) from the sampling frame in accordance with the area used for the 2011 Population and Housing Census.

Favourable environmental features, such as warm to hot mean temperatures, a long rainy season, and forests, all contribute to the quick establishment and spread of FAW pests in Africa. Larger sections of Sub-Saharan Africa are very favourable for FAW throughout the year, whereas other regions, such as parts of Southern Africa, the DRC, Congo, Cameroon, and Gabon, are less favourable. Even though there have been no instances of FAW outbreaks, some coastal regions in North Africa are advantageous because, according to the model developed by Cock et al. (2017), FAW are known to be migratory pests and have not yet reached the aforementioned regions.

2.2.9 FAW outbreak in Namibia

The first FAW outbreak in Namibia was recorded in 2016 (FAO, 2018). Farmers reported another second outbreak of FAW in northern Namibia, in Omusati, Ohangwena, Zambezi, Kavango East and Kavango West regions in January 2017 (FAO, 2018).

Figure 2: Leaf damage by FAW in Kavango East region

Source: MAWLR, 2020

According to Heinrichs et al., (2017) young larvae graze on the leaf surfaces around the midrib as they grow. The FAW has the potential to destroy young plants while only defoliating mature ones (Heinrichs et al., 2017). If there are a lot of armyworms present, young seedlings may suffer severe stand loss. Defoliating pests largely reduce crop yield potential by impairing photosynthesis in the plant (Aguirre et al., 2016). More than 60 plant species, such as forage grasses, corn, alfalfa, cotton, soybeans, and most vegetable crops, are infested by fall armyworms (Nagoshi et al., 2008). Early signs of damage include a dark brown hue or burned-out region that resembles dead or drooping leaves, which are symptoms comparable to drought stress. This patch expands as FAW spreads and eats more vegetation (Flanders et al., 2017). Due to the larvae eating everything but the ribs and stalks of maize plants, damage to plants is frequently severe. By digging into the bud or whorl and pinching the leaves, the larvae might obliterate the plant's growth point. Additionally, it has been noted that the FAW will occasionally eat a maize ear. Contrary to the corn earworm, which prefers to eat through the silk at the tip of the ear, the fall armyworm prefers to burrow through the side of the ear through the husk (McCullars, 2019). The adult stage of the FAW life cycle is the moth. If these moths are present in a field, it is advised to search the area for eggs and larvae because they can be seen in pheromone or black light traps (McCullars, 2019). Early in the season, when there are six or more armyworms per square meter, and late in the season, when armyworms are discovered eating and harming the flag leaf, treatment is the normal criterion for FAW in maize. Field edges need to be watched for armyworm migration from other field crops. Use insecticide treatment before serious damage begins (Hardke, 2019).

2.2.10 Gender differences in FAW control in Ghana and Zambia

The common home management measures were found to vary by gender in Tambo et al. (2020) study on FAW control practices by farmers in Ghana and Zambia. Tambo et al. (2020) claim that both households with male and female heads use pesticides to manage FAW in Ghana and Zambia. However, female-headed families in Ghana employed more agronomic techniques than male-headed households, who relied more on traditional techniques including hand-picking egg masses, weeding, and uprooting diseased plants.

2.2.11 Effects of FAW outbreak in Namibia

Several insect outbreaks had previously affected farmers in Namibia, but most recently, FAW was documented between December 2016 and February 2017. A significant portion of the maize and millet crops were at a delicate growing stage during this time (FAO, 2018). The north-central and north-eastern regions of Namibia, where maize and mahangu crops are traditional staple foods, were particularly hard hit by the FAW outbreak, according to Ewi published in 2017.02.22. As a result, Namibia's food security was put in jeopardy. According to a 2017 report by the UNOCHA on the effects of the FAW outbreak in Southern Africa, Namibia's pearl millet production was affected on communal land to the tune of 12,400–16,000 hectares, directly affecting 20,673 households (Ganige et al., 2018; Sharanabasappa et al., 2018). The north and north-eastern parts of Namibia, particularly Kavango East, were additionally reported to have 37 percent of pearl millet farmers and 9 percent of sorghum farmers afflicted by FAW (FAO, 2018). It was predicted that the yield loss in the regions with the highest percentage of impacted plants, which include Kavango East region, were correlated with the proportion of affected crops in the affected fields given the extent of the cereal crops' damage (FAO, 2018).

2.2.12 Economic impact of FAW outbreak on pearl millet output

FAW outbreaks can result in severe loss of pearl millet and other crops if they are not handled or controlled by natural biological means (De La Rosa-Cancino et al., 2016). When calculating the probable yield loss due to FAW infestation, there are numerous factors to consider (Kumela et al., 2019). Some of the factors include knowledge of control measures, environmental conditions of the area (soil fertility and local climatic conditions), and access to agricultural extension services (Kassie et al., 2020). A study on economic impacts of FAW in Ethiopia found that knowledge and use of combining strategies (chemical control, biological and manual handpicking of insect from the crop) is significantly effective in protecting yield loss from FAW as farmers who employed a combined strategy managed to protect their yield after a FAW infestation in comparison with those who failed to employ any strategy at all (Kassie et al., 2020).

The study also showed that access to extension services and FAW control had no discernible effect on lowering the possibility of yield loss brought on by FAW infection (Kassie et al., 2020). In general, the population density and the plant's health and vigour (nutritional and moisture condition) have a significant impact on how the crop reacts to an FAW infestation (Aguirre et al., 2016). The most frequently cultivated crops in Africa are maize and pearl millet, which provide a staple meal for about half the population. Over 200 million people in Africa's different Agro-ecological zones depend on the crop for their food security. Nearly half of the calories and protein consumed in eastern and southern Africa come from maize (Macauley, 2015). In Ghana, the estimated national mean loss of maize in July 2017 was 45% (range 22–67%), and in Zambia, the projected national mean loss was 40% (range 25–50%) (Day et al., 2017). Day, et al. (2017) analysed the possible effects on national production and income in 10 other major maize-producing countries, if the FAW will spread throughout all locations where it is anticipated to thrive. They did this by using the data from Ghana and Zambia as a benchmark. The impact of Fall Armyworm epidemics on household livelihoods is diverse. According to the British Department for International Development's (DFID) livelihood framework, pests have an impact on two types of capital: natural capital, which is affected by yield losses and the ability of agricultural lands to recover from shocks; and financial capital, which is affected by rising production costs and their impact on income. Additionally, it indirectly impacted the social and physical capital of households (Day et al., 2017). In addition to having an impact on output, market factors can also change pay for agricultural and processing jobs and otherwise have an impact on upstream and downstream operations (Fermont & Benson, 2011). Infestations or outbreaks can cause prices to spike abruptly if most of the production is consumed domestically. A fall armyworm infection results in poor crop quality and quantity, which lowers the crop's selling price. The relative elasticities of demand and supply, or the responsiveness of demand and supply to price changes, determine the proportionate consequences of the output deficit on producers and consumers. Trade runs the risk of bringing pests into nations where they are not yet a problem; shipments of food and agricultural products are one such example. Trading blocs frequently control this risk by adding extra production or handling standards and restrictions to shipments from FAW-affected nations, which has an economic cost to the exporters. Countries that are devoid of significant pests would typically preserve their domestic agriculture by either completely banning the importation of goods from pest-and disease-affected regions or by making importation subject to several safety precautions. Many efforts to eradicate plants and diseases are motivated by the desire to acquire access to high-value export markets (Kassie et al., 2018).

2.2.13 FAW strategies used by farmers to control the outbreak

According to Tambo (2019), the main control methods used to manage the outbreak of FAW included pesticide application and handpicking of larvae, meanwhile access to information on FAW was a key driver behind the implementation of the control measures put in place. His results showed that the implementation of a FAW management strategy significantly enhanced maize yield and household own maize consumption, he also found that the combination of cultural handpicking of larvae and application of pesticides yielded the highest harvest of 100%. The results of his research demonstrated that farmers' efforts to control the FAW infestation had successful results, even though more action is still needed to effectively manage the pest, including raising awareness to encourage the adoption of control interventions and considering alternative options (Tambo et al., 2019). When compared to planting later maturing types, planting early maturing corn enables the crop to avoid having excessive densities of FAW (FAO, 2019). Reduced tillage does not seem to have an impact on fall armyworm populations (All, 1988). McCullers (2019) distinguishes between primary and secondary cultural control strategies. Planting a trap crop is the primary cultural control method used to specifically control insects. Normal preparations e.g. weeding, uprooting, and burning infected plants are examples of secondary actions that in turn lower insect populations (Flanders et al., 2017). The planting method, which determines planting time and plant density, also contributes to pest management. Before planting, tillage of the soil reduces insect populations by burying, crushing, and exposing pests to desiccation and predators (Tambo et al., 2019). Another significant cultural practice is weeding. Crop rotation is most effective when used against species that have constrained host ranges, slow dispersal, and extended life cycles (Hackett & Bonsall, 2016). Another suggestion for controlling armyworms is crop rotation. Because the vegetative growth stage is shorter in early maturing cultivars, it may be detrimental to the growth and development of armyworms (Hardke, 2019). Crop productivity also depends on the timing of planting. Between the weed host and the pearl millet crop, weeds serve as a link. For the control of armyworms, weeding the crop is advised (Hackett & Bonsall, 2016).

2.3 Summary

Chapter 2 explored the literature related to the effects of the Fall Armyworm which includes the current knowledge including substantive findings, as well as theoretical and methodological contributions. The review enumerated, described, summarized, objectively evaluated, and clarified previous research whilst giving a theoretical base for the research and helped the researcher determining the nature of the research. Chapter 3 further develops the research by providing the research methodology.

Chapter 3: Methodology

3.1 Introduction

This chapter presents the study area, research design, sampling procedures and the selection of farmers who participated in the study. The chapter further gives the details on data collection, data analysis and potential complications.

3.2 Study area

The study was conducted in Kavango East region of Namibia, in Rundu urban, Rundu rural, Mashare, Ndonga Linena, Ndiyona and Mukwe constituencies. The region has a population of about 139 823 (NSA, 2015). Kavango East is ranked the second poorest region in Namibia after Kavango West (Hardke, Huang, Jackson, & Leonard, 2011). The selection of the study area was based on the prevalence of FAW outbreak in the region. Figure 4 below shows the geographical position in the Namibian map.

Figure 3: Study area

Source: Namibia Statistics Agency, 2015

The climate of Kavango East region is semi-arid with average total annual rainfall of 570mm characterized by high rainfall variability, frequent droughts, low soil moisture and extreme events such as flash floods (Hill et al., 2014). Temperatures vary during the year with high average summer temperatures of about 30°C and low winter temperatures of below 10°C (MLR, 2015).

The farmers in Kavango East depend on primary production and rain-fed agriculture. Most of the farmers do mixed farming for coping strategy. The advantages of mixed farming are for both crop farming and livestock farming to complement each other. Oxen are used for draught animal power during land preparation, whereas livestock manure is used as fertilizer in crop fields. Although, the area is considered unfavourable for dry land cropping, farmers grow drought tolerant varieties of mahangu. Crop farming is predominantly practiced with pearl millet followed by maize as main crop (Ahmad, Javaid, Khaliq, & Ullah, 2017). Livestock in the area is mainly cattle and goats and these are regarded as traditional assets for meat, milk, and income. Some farmers who reside along the Kavango River supplement their livelihood with fishing activities. Apart from farming and fishing, other farmers make a living on craftwork for income as they sell craft materials to tourists (Strohbach, 2013).

The communal land is being governed by the traditional authorities. The land is in the hands of the community members to share the resources found within the jurisdictions of their areas. They are various leaders found in the communal areas, of which are traditional leaders such as chiefs, head men/women. They are also regional committees, for instance, constituencies' development committees, village development committees and pastors from various church leaders.

Participation of farmers in agricultural programs is an important factor as it plays major role in poverty alleviation in rural communities, improvement in decision making capacity, use of chemicals farm productivity improvement and acquisition of new knowledge in agriculture (Karbasioun, Biemans, & Mulder, 2008; Corner-thomas et al., 2015; Xian-ming et al., 2021).

3.3 Research design

3.3.1 Quantitative research design

In quantitative research, we study variables like dependent, independent variables that predicts or explains the main variable, which is the dependent variable, there is also confounding or in other terms extraneous variable. Furthermore, the dependent variables are influenced by the independent variables in the study, and bewilder variables are the confounding or in other terms extraneous variable. A study can have a lot of independent or explanatory variables studying the dependent variables. In this specific study our dependent variables are expected yield and actual yield and the independent variables are area planted, fertilizer used, fertilizer quantity used, Mahangu, maize, cowpea, methods used to prevent/control the attack of Fall Armyworm severity and outbreak. Confounding variables are age, language, gender, and constituency.

3.4 Sampling

The target population of the study was the small-scale farmers in Kavango East region who participated in this study. A total of 100 farmers participated in the survey. Farmers were randomly picked from the 6 (six) Agricultural Development Centres' lists, namely: Rundu Rural, Kaisosi, Mashare, Ndonga Linena, Ndiyona and Mukwe across the Kavango East region. The sampling was done by looking at registers/lists of farmers collected from various ADCs in the region. The population size of farmers for Kavango East is 59 404.

3.5 Data collection

Primary data was collected using questionnaires, interviews, and observations. Questionnaires and interviews were administered by the researcher. Questionnaires were used to gather data that have quantitative features from respondents. This was done by estimating the pearl millet yield estimates on the expected and the actual volumes produced for consumption and marketed in Kavango East during 2017 to 2019 cropping seasons post the outbreak period. The Ministry of Agriculture, Water and Land Reform analysed secondary data from sources including books, journals, and publications of government ministries and agencies. From September 5 to December 5 of 2020, the survey was carried out regionally. The difficulty encountered throughout the data collection phase was that some farmers were reluctant to supply all the required information in response to the questions posed.

3.6 Data analysis

The data collected was captured in Microsoft excel sheet, cleaned, and coded accordingly. The data was then transferred to R software (version R-4.2.1) for analysis. The expression was created and came about as a programming expression for data analysis duties but in fact it is a full-featured programming expression in its present executions. To test the hypotheses on the significant difference in pearl millet yields for farmers and FAW outbreaks, the effectiveness of different strategies used to control FAW outbreak and farmers' incomes, statistical regression analysis using different methods and the results are presented in Chapter 4 of this Thesis. Three statistical models were applied to achieve the objectives of the study and are discussed as follow:

ANOVA was used to analyse the first object of the study in determining the direct impact of the pest outbreak on pearl millet output by comparing the expected and actual yields. The same model was used to determine the impact caused by the outbreak of fall army worms during 2017 to 2019 cropping seasons. The second objective was achieved by using chi-square to determine the severity FAW had in the livelihood of farmers. Descriptive statistics was used to quantify the mitigation measures that farmers took to reduce the severity impact of FAW on crop output.

3.6.1 ANOVA

Analysis of variance (ANOVA), according to Sawyer (2009), is a statistical procedure used to spot variations in experimental group means. ANOVA is appropriate for experimental designs with numerous experimental groups within one or more independent (categorical) variables and one continuous parametric dependent variable. Independent variables are referred to in the ANOVA language as factors, and levels are introduced for each factor's subgroups. The variety of terms that make up the ANOVA package, such as dividing of variance, main effects, relations, factors, sum of squares, mean squares, F scores, family wise alpha, multiple comparison procedures (or post hoc tests), effect size, statistical power, etc., can be intimidating to those who lack statistical expertise. ANOVA is technically established on generic linear models and linear regression to measure the relationship between the dependent variable and the independent variable(s). For ANOVA, there are three different general linear models:

(i) The fixed effects model (Model 1) draws conclusions specific to the populations and study treatments only. For instance, if a medicine is administered in three different dosages as part of three different treatments, then only those exact drug doses can be inferred. The experimental design explains why each factor's levels are fixed.

(ii) The random effects model (Model 2) draws conclusions regarding levels of the component that were not included in the study, such as a continuum of drug doses when only three doses were employed. This model outperforms random influences within levels and draws conclusions about the random variation of a population.

(iii) Fixed and Random effects are both present in the Mixed Effects Model (Model 3). The fixed effects model is crucial in most clinical studies on orthopaedic rehabilitation since the levels of the experimental design are fixed to the statistical inferences being sought. Higher end computer statistical tools can do ANOVA with all three models, although fixed effects models are often important for ANOVA analysis.

ANOVA uses computations of "Sum of Squares" and "Mean Squares" to infer the "splitting of variance" and assesses dissimilarity in group means in a circumstantial manner. The ANOVA test statistic, also known as the F score (after R.A. Fisher, the inventor of ANOVA), is calculated using three metrics:

(i) Grand Mean, which is the average of all scores across all groups.

(ii) Sum of Squares, which comes in two forms: the Grand Mean and the sum of all squares combining group means (between-groups Sum of Squares) and the sum of squares comparison between individual data scores and their group mean (within-groups Sum of Squares).

(iii) Mean Squares, also of two types (between-groups Mean Squares, within-groups Mean Squares), which are the average deviations of individual scores from their specific mean, calculated by dividing Sum of Squares by their appropriate degrees of freedom.

A crucial aspect of ANOVA is that the F score is produced by separating the data set variance into statistical signal and statistical noise components. For autonomous groups, the F score is determined as follows:

F is the product of statistical noise and signal.
F is equal to the treatment effect minus the error variance.
F is the product of the mean squares within and between groups (Error)

It should be noted that the MS allying Groups term, a statistical signal, is a deviant measure of group mean dissimilarities. Since this variance is not explained by the impact of the independent variable on the dependent variable, the MS within Groups (Error) term is thought to represent statistical noise or error. The main problem is as follows: The variation for allying-group scores in relation to the Grand Mean, measured as Sum of Squares allying Groups, increases when group means diverge from one another. This leads to a bigger MS allying Groups term and a larger F score. Additionally, the MS within Groups (Error) term will grow as there are more variance within-group scores, as measured by the Sum of Squares within Groups (Error), resulting in a smaller error. Big F scores therefore result from large differences between group averages and/or limited variances within groups for independent groups. Lower p values are associated with higher F scores, and the p value is also influenced by sample size and the number of groups, both of which take into consideration different kinds of "degrees of freedom." Nowadays, computer software is used to execute ANOVA calculations, but performing the mathematical computation of the F score by hand can provide insight into how analysis of data set variance leads to a statistical conclusion regarding differences in group averages.

3.6.2 Chi-squared tests

Chi-square test is used to find out any correlation among non-numeric variables that are frequently used in statistical studies (Kothari, 2007). It is symbolized as χ2. Kothari (2007) stated that the following requirements must be fulfilled before the test:

(i) Observed and expected observations are to be collected randomly.
(ii) All the members (or items) in the sample must be independent.
(iii) None of the groups must contain very few items (less than 10).
(iv) The number of total items must be quite large (at least 50).

The value of Pearson's Chi-square distribution is that statisticians can apply statistical techniques. Karl Pearson (1857–1936) was the person who initially created the reasoning behind hypothesis testing (Magnello, 2005). The most important contributions Pearson contributed to current statistics theory were the development of the chi-square goodness of fit tests, independence tests, and homogeneity tests that do not rely on the normal distribution when interpreting results. A Chi-square table and the appropriate degree of freedom and significance are used to calculate the significance of the Chi-square value (Moore, 1994). The Chi-square test has two specific goals: to determine whether there is no association between two or more groups, populations, or criteria, and to determine how well the observed data distribution matches the predicted distribution.

The single sample goodness of fit test or Pearson's Chi-square of goodness of fit test are other names for the chi-square of goodness of fit test. This test is a nonparametric single-sample test. I Cases are derived from a single category variable (such as participants). For instance, "educational background" could be divided into "high school" and "university" groups.
Distribution is derived from a known or predicted distribution in (ii).

For instance, a known distribution, like the ratio of educated to illiterate people in a nation, or a speculated distribution, like the ratio of males to women taking the university admissions exam the following year. It is crucial to "hypothesize" whether we can anticipate that the cases in each group of the categorical variable will be "equal" or "unequal" while the Chi-Square goodness of fit test is being used. According to Mutai (2000), the goodness of fit test does not directly compare empirically obtained data to theoretically predicted outcomes (expected to be frequencies).

Finding degrees of freedom, expected frequency counts, test statistics, and P values associated with the test statistic are necessary in data analysis. Degrees of freedom (DF) are equal to the categorical variable's (k) levels, minus 1.
DF = k – 1

The predicted frequency counts for the categorical variables at each level are equal, and the null hypothesis is used to estimate the sample size for the rate.
Ei = npi

Pi is the estimated rate of the observations at the I level, n is the overall sample size, and Ei is the predicted frequency for the i^{th} level of the categorical variable. The formula below is used to determine the Chi-Square goodness of fit test value: X2 = [(Oi - Ei) 2/Ei] Where Oi is the observed frequency count for the categorical variable's i^{th} level and Ei is the anticipated frequency count for the same level.

The Chi-square goodness of fit test's H0 hypothesis is as follows: Data have a predetermined distribution. H1: The specified distribution of the data is not observed.

The sample considerably differs from the population in terms of the correlation variable, according to the comment on rejection.

3.6.3 Descriptive Statistics

Brief descriptive coefficients are used to create a data set that represents the complete population or a sample in descriptive statistics. The primary goal is to give an overview of the samples and measurements used in a study. When combined with various graphic analyses, descriptive statistics make up a significant portion of any quantitative data analysis. Compared to inferential statistics, descriptive statistics focus more on characterizing the data being displayed. Inferential statistics, on the other hand, deals with drawing a conclusion from the available data. Descriptive statistics are primarily used to explain how a sample of data behaves. It serves as a means of presenting a quantitative analysis of the given data collection. As there are many variables to be measured in a study, descriptive statistics is used to reduce this vast amount of data to its most basic form. For instance, learning the average number of passes a football player makes throughout a game might be intriguing. Now that there are numerous activities within a single game, we can use descriptive statistics to streamline that. Measures of central tendency or measures of variability can be used to quantify descriptive statistics. These two approaches employ tables, graphs, or general explanations to aid viewers in comprehending the precise significance of the studied data. Measurements of central tendency and measures of dispersion are two alternative ways that the data might be described.

Measures of central tendency provide an overview of all the data and metrics that make up the full set. For a specific data set, it describes the location of any distribution's center. We use a mean, median, and mode that measure the most prevalent patterns of the examined data set to analyse the frequency of the data point in the distribution characterizing it. It is the most thorough description of any population's characteristics. Three metrics exist for central tendency:

a) Mean: defined as the total number of values divided by the sum of the values of the variables.
b) Median: the midpoint.
c) Mode: the value that occurs most frequently.

Example: The ages of five students who were chosen at random and who were applying to Ivy League Universities were 23, 25, 27, 29, and 31.
(23+26+26+29+31) / 5 = 27 years of age is the mean.
Age Median: 26 years

Age Modal: 26 years

The Mean value is the most popular way to measure a trend. When some numbers are significantly different from the rest, medians are occasionally utilized (this is called a skewed distribution). Comparing the earnings of randomly chosen individuals may reveal that most people must be earning between $0 and $200,000, while a small number of them make in the millions, according to the National Centre for Children in Poverty (2019).

The range or spread of the values described for a variable can be learned via measures of dispersion or variation. It examines the distribution spread that is determined for a given data collection. For instance, the central tendency measures can provide the average of a particular data set, but they are unable to explain how the distribution of the data set was accomplished. The following are the main indicators of dispersion:

a) Range is the difference between the smallest and largest value throughout the entire data collection.

b) Variance: this concept evaluates how far apart a set of statistics or data is from their mean value. It is computed by averaging the squared disparities between each value and its Mean.

When a set of data spreads out from the mean, it is measured by the standard deviation, which is the average distance between each quantity and its means. A low standard deviation indicates that the data points are relatively close to the Mean, whereas a large standard deviation indicates that the data points are dispersed throughout a wider range of values.

3.7 Summary

Chapter 3 explored the research design used for the study and how data was used to analyse the 2016/17 impact caused by FAW outbreaks on farmer' crop yields and livelihoods. It outlines how the first objective was achieved by analysing primary data. The sampling was done by looking at registers/lists of farmers collected from various ADCs in the region. Primary data was collected using questionnaires that were administered by means of interviews and observations. It was used to gather data that have quantitative features from respondents. This was done by estimating the pearl millet yield estimates on the expected and the actual volumes produced for consumption and marketed in Kavango East region during 2017 to 2019 cropping seasons post the outbreak period. Secondary data was reviewed from sources like books, journals, publications of government ministries and agencies under the Ministry of Agriculture, Water and Land Reform.

Chapter 4: Results and Discussion

4.1 Introduction

This chapter presents the results of the study conducted to investigate the 2016/17 impact caused by Fall Armyworm (FAW) outbreak in farmer's crop yields and livelihoods in Kavango East region in Namibia. The results are from the data collected from 100 farmers from Kavango East region. The results are presented in pie charts and bar graphs, while for each bar graph are described, interpreted, and discussed by linking them to literature where applicable. The results in this section are presented in line with the structure of the research instrument used. They are divided into two sections that include the characteristic of respondents and the statistical result of the study.

4.2 The characteristic of the respondents

4.2.1 The geographical location of respondents

The respondents participated in the study were interviewed in different constituencies of Kavango East region and Figure 1 below displays the geographically distribution of the farmers who were interviewed.

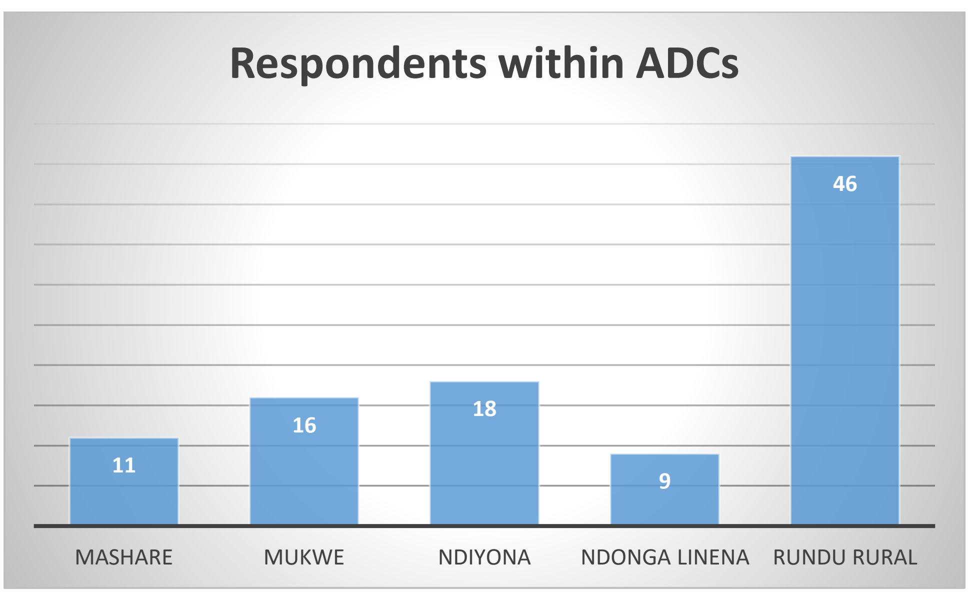

Figure 4: Regional Constituencies

Figure 4 above indicates that majority 46% of the respondents were from Rundu Rural constituency reason being that they were easily reached since it's close to town saving resources and time for travelling long distance. The minority 9% are from Ndonga Linena since it is further from town.

Most respondents came from Rundu Rural because it was closer to Rundu town, and this made it easier for the Researcher to reach out to them. In addition, more farmers were willing to take part in the survey. The study also found that more farmers were, registered under Kaisosi ADC that falls under the above-mentioned constituency. Farmers living closer to town are more open and willing to be interviewed and have a good understanding of research unlike farmers who lives away from town due to exposure of research, because their nearby areas to town are easily accessible by any Researcher at any given time. Another reason that contributed to the further constituency having fewer respondents is because it was costly for the researcher to travel more often thus one trip per day was planned for each constituency and the number of farmers that were available became the representative number for that constituency.

4.2.2 Household head gender

Gender is a factor that was considered to understand the characteristic of demographic distribution of farmer in the constituency as this influences the decision-making process in the management and administration of farming activities. The gender distribution of the respondents who participated in the study is displayed in Figure 6 below. According to the study female farmers head most households.

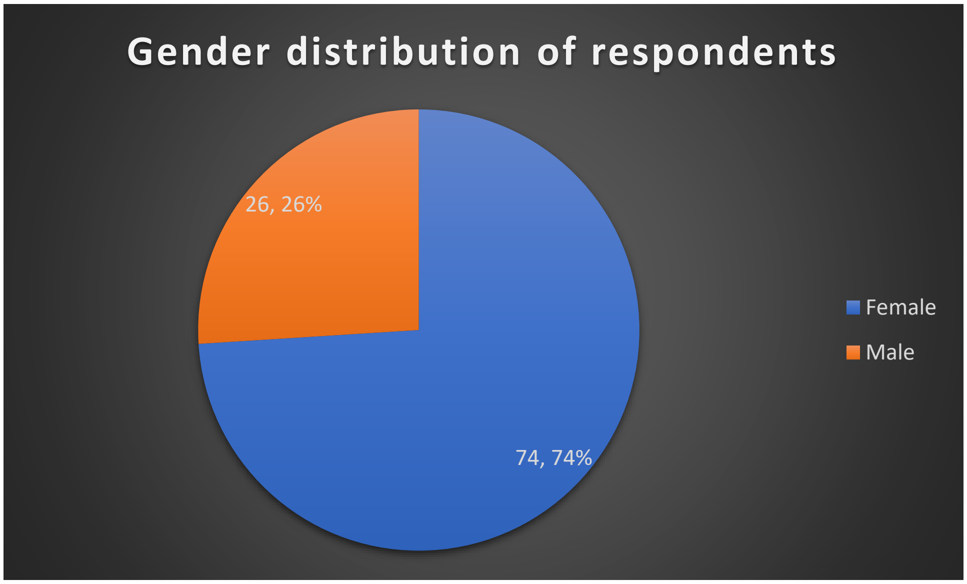

Figure 5: Gender of farmers

Figure 5 above shows that 74% of respondents were female and 26% were male. This means that most of the people that took part in this study were female that showed that more women are involved in agricultural activities than men in Kavango East.

4.2.3 Age distribution

According to Namibia Statistics Agency (NSA) (2015), the 41 years and above age-groups are commonly found in rural areas as farmers because of return migration or a few who never migrated. Furthermore, Liu, Du, and Fu (2021) stated that elderly farmers are not good at directly adopting modern agricultural technologies and production modes due to their low level of education, conservative ideas, and poor ability to accept new things. Therefore, this can affect the understanding and adoption of modern methods of FAW control.

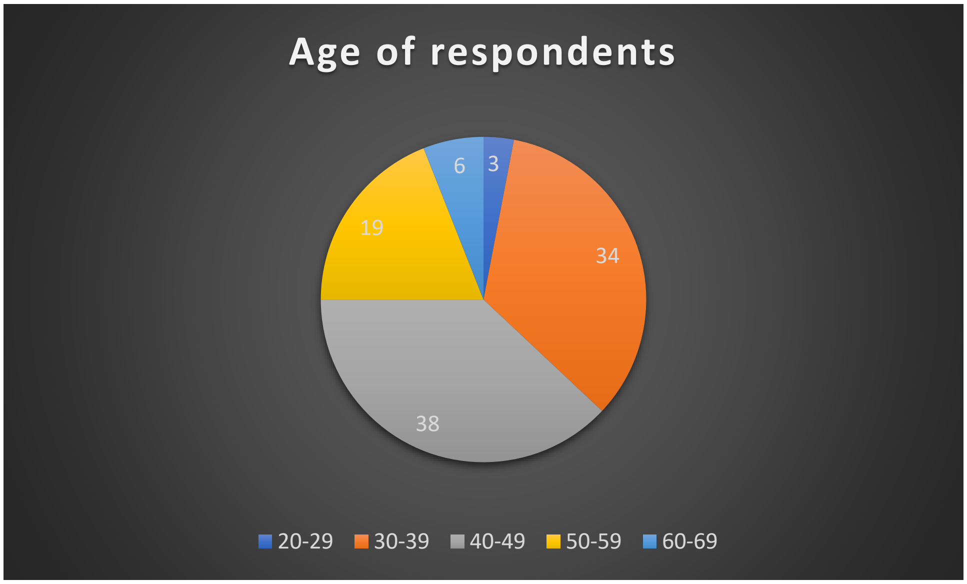

Figure 6: Age group of farmers

Figure 6 above shows that majority, 38% of the respondents that took part in the study were from the age group of 40-49. The minority, 3% are from the age group 20-29, this shows that young people are lacking in the agricultural activities, and it affects the future of Agricultural activities in this region.

The result suggests that most farmers in Kavango East region are above 40 years. The results agree with the fact that rural to urban migration is more concentrated at ages 20-34 young adult ages at which work, and family factors may lead to greater mobility (Namibia Statistics Agency, 2015).

4.2.4 Education level of the respondents

Education is a factor in the characteristics of a farmer because it improves agricultural productivity in that formal education broadens the farmer's mind, non-formal education provides hands-on training and better farming techniques, and informal education keeps the farmer up to date with changing conditions. This variable considered the education level of the interviewee, not necessarily the education level of the household head. The education level of the respondents who took part in the study is shown in Figure 8 below.

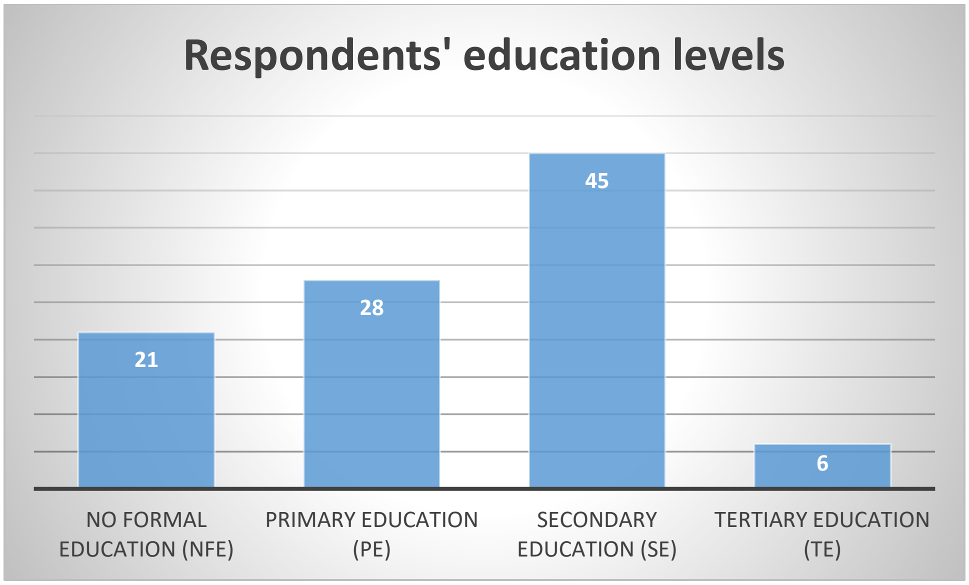

Figure 7: Education of farmers

Figure 7 above shows that 45% of respondents had secondary education and few 6% had tertiary education. As the educational level of farmers increase, the output increases having highest yields in agricultural production, education enhances the farming skills and productive capabilities of the farmers. So, in this study the fact is that most of the respondents had secondary education.

4.2.5 The analytical result of the study

4.2.5.1 Direct impact of FAW outbreak on pearl millet output

Two sets of data—the expected and actual yield gathered over the course of three production seasons—were utilized to assess the influence of the FAW outbreak on pearl millet output, which was objective 1 of the study. The mean yield of pearl millet was compared using Welch's t-test, also known as an unequal variances t-test, and the significance level was established using the corresponding p-value. The mean yield of pearl millet over three years, the mean yield of pearl millet within each year, and finally the difference in real yield over three years were tested in three different processes.

4.2.5.2 The difference in expected and actual yield across all years

The first test done was to find out if there is a difference in expected and actual yield on pearl millet across three years.

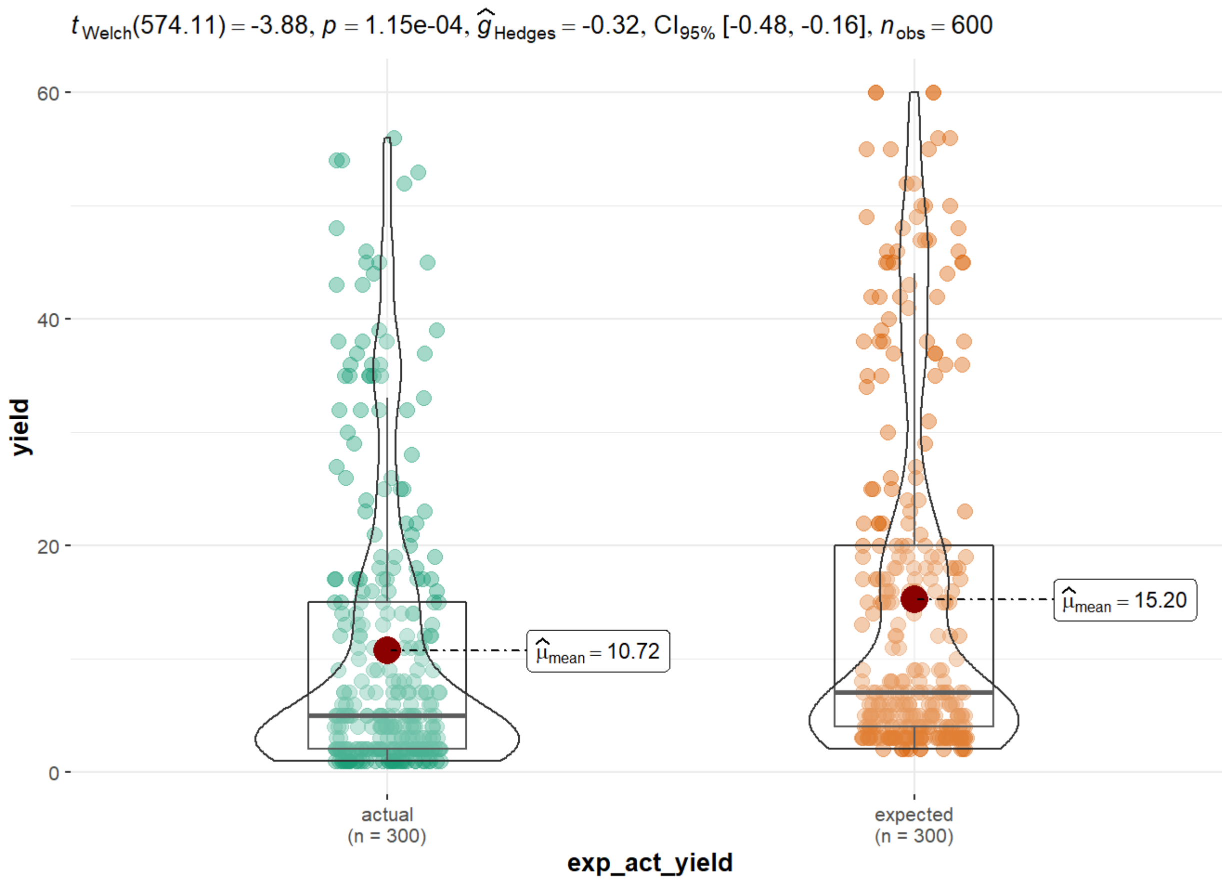

Figure 8: Expected and actual yield difference over three seasons of pearl millet

The Welch's *t*-test indicates that there is a highly statistically significant (p<.0000115) difference between the expected and actual yield over three years. The difference in the expected and actual yield can be seen in Figure 8 above. On average farmers expected to receive 15 bags over the three seasons but they only harvested an actual yield of 11 bags over three seasons. Thus, the difference in terms of bags is attributed to the outbreak of FAW because it negatively reduced the actual yield. Farmers usually project their yield based on the area planted, the germination and growth rate of their crops. However, FAW outbreak occurred at a later stage just before the pearl millet starts forming heads causing devastating damage to the crop's physiological development that eventually tempered with the ability of crops to bear a good harvest.

4.2.5.3 The difference in actual and expected yield in each year

The second test was carried out to determine the difference between the expected and actual yield within each year. This test was necessary to determine which year has contributed more to the overall significance found in the first test.

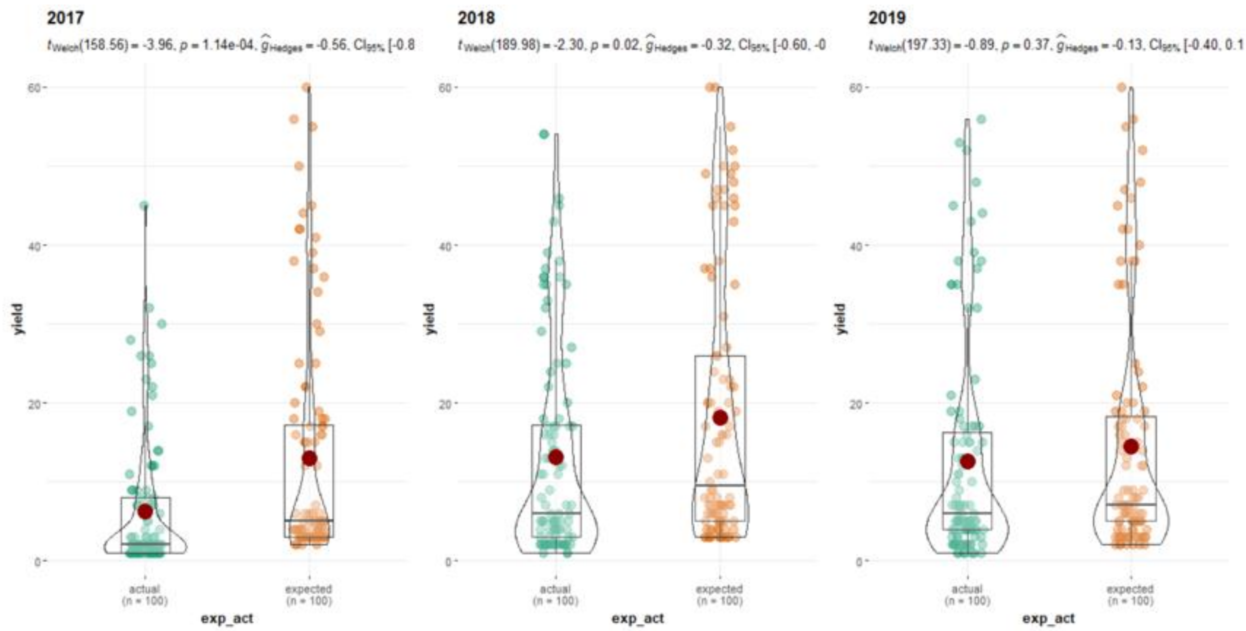

Figure 9: Difference between expected & actual yield per season of pearl millet

The second test revealed that there was a statistically significant difference in terms of expected and actual yield in the 2017 and 2018 seasons and no statistically significant difference in the 2019 season. This is a clear indication that the first two cropping seasons contributed to the overall statistically significant difference observed over the three cropping seasons. As shown in Figure 9, the significant difference in 2017 is shown statistically with p<.0000114. On average farmers expected almost 13 bags but only harvested actual 6 bags. This is because the outbreak of FAW occurred in Namibia for the first time in this season of 2016/2017, farmers were not aware of the destructive capability of this worm, and they did not know what they could do to control the outbreak. This gave leeway to the FAW to cause as much damage as it could to the crops.

The significant difference in 2018 is shown statistically with p <.02 and the means average clearly indicates that there is a difference. In the second season, farmers had known about the outbreak of FAW from the previous cropping season and might have tried some mitigating measures. However, because the FAW have laid eggs in the previous season and transformed into other stages, in the second season the number of the worms increased, and the distraction extended. Farmers in this case were not permitted to use pesticides as a controlling method by the Ministry of Agriculture, Water, and Land Reform, so they tried a variety of other approaches, but their efforts were unsuccessful. Due to the area's high rains, farmers anticipated a good crop this season.

Because the $p<.3$ is bigger than the $p<.05$., there was no statistically significant difference between the expected and actual yield in the third season. This is due to the strict controls the government implemented through the Ministry of Agriculture, Water, and Land Reform to make sure pesticides were ordered on time and the team was prepared to control the FAW outbreak as soon as the farmer notified the Ministry through their closest extension offices. This demonstrates that the difference between the anticipated and actual yield of pearl millet was considerably influenced by FAW.

4.2.5.4 The difference in actual yield across the three cropping seasons

The third and last test was to analyse the difference in the actual yield over the three cropping seasons. This test was carried out to see trace the impact on actual yield across the seasons.

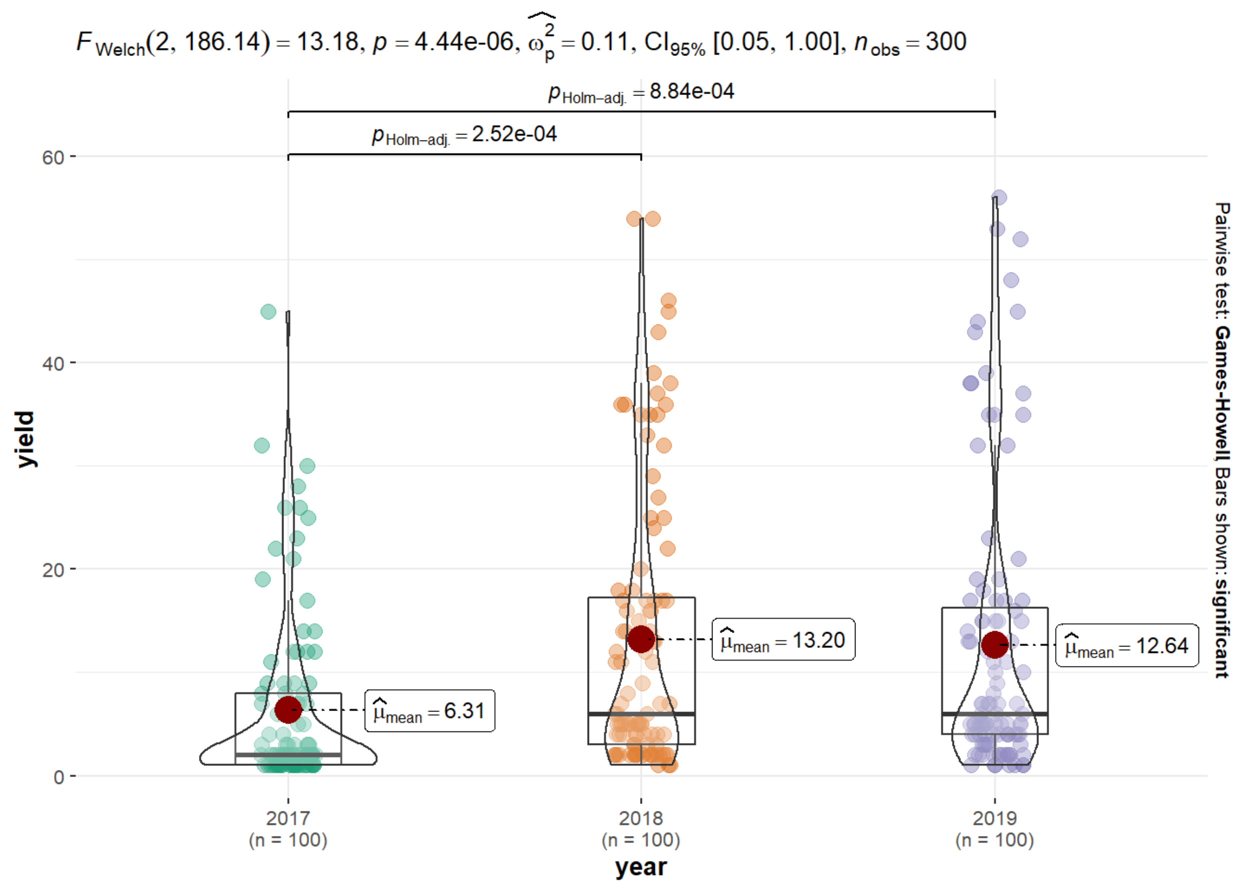

Figure 10: Actual yield difference over three seasons

The Welch's *t*-test indicates that there is a statistically significant difference ($p <.00000444$) in actual yield across the three cropping seasons. As shown in Figure 10 above, the average number of bags harvested in the first season of the FAW outbreak was only 6 bags, this revealed that the outbreak caused a massive distraction to the pearl millet yield because farmers were not aware of this fall armyworm hence, they did not take any action to control it. Due to the lesson learned in the first season, farmers applied different strategies such as early planting, apply of ash on their crops and some tried sprinkled water mixed with chilli. Thus, the actual yield was better in the second and third seasons than in the first season. Hence, we conclude that FAW did influence the yield of pearl millet statistically significantly in the region and FAW occurred unexpectedly in the first season. Farmers were surprised and had no idea on how they should control the armyworms, they panicked and were confused. Although they tried different methods to reduce the effect, the FAW continued causing devastating damage to the pearl millet. The drastic measure taken by the government to control it chemically showed positive breakthroughs.

4.2.5.5 Severity of FAW on the farmer's crop yield and livelihood

To determine the severity of the FAW, chi-square test was carried out and the result of the test are displayed in the Figure 11 below. The analysis of severity of FAW in the livelihood of farmer with chi-square test indicates that there is a statistical significance difference amongst farmers who experienced the outbreak. The *P*<.1.98e-72 reveal the rejection of the null hypothesis and acceptance of the alternative hypothesis.

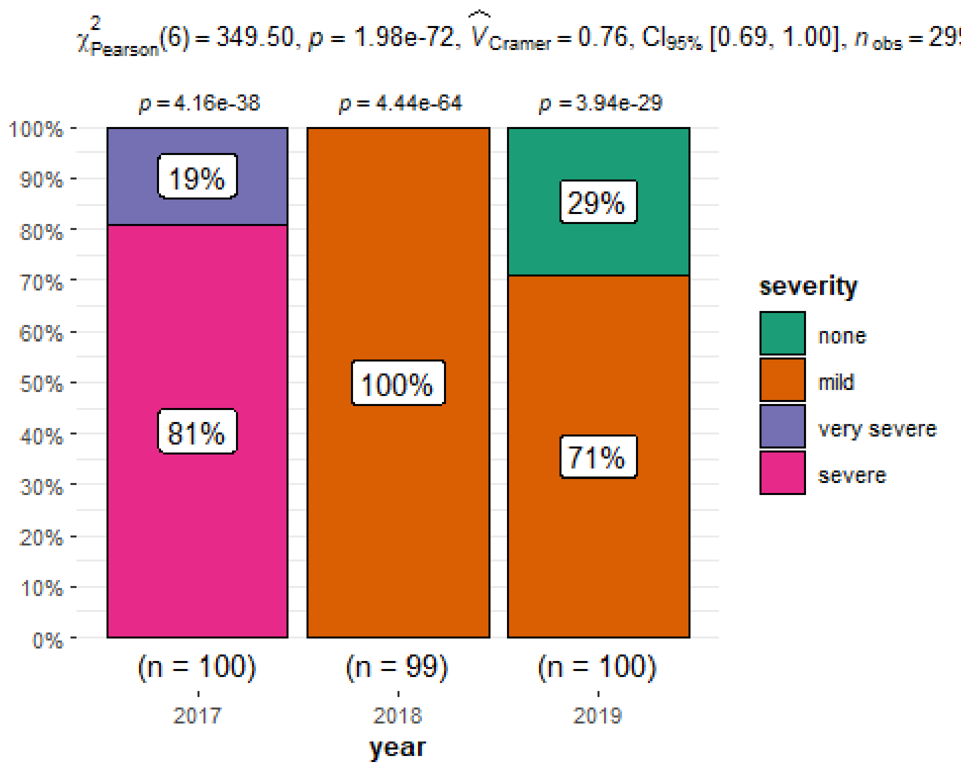

Figure 11: Severity of FAW outbreak over three seasons

Because this was the first planting season the outbreak occurred, Figure 11 above shows that farmers were badly impacted in the year 2017. Because farmers were unaware of the FAW, they lacked expertise and knowledge regarding how to manage the outbreak. Farmers were watching their crops being damaged by FAW in a panicked state due to their lack of expertise, and the severity of the damage was greater in the first season (2016/2017) that the FAW occurred. Because farmers discovered more effective or creative ways to lessen the effects of the FAW, the data showed that farmers only suffered a modest severity during the second cropping season.

The analysis has proved that the FAW had dare consequences in the livelihood of farmers because the damage suffered by crops did not only deprive them of good yield as a source of food, but it came as a loss in terms of income generation that they could have received if they produced in surplus for marketing.

4.2.5.6 Strategies and methods used to control FAW outbreak

The techniques/strategies adopted by the farmers in their cooperation with the Ministry of Agriculture, Water and Land Reform as mitigating measures to control the outbreak of FAW were identified using descriptive statistics. The P-value for the analysis suggests that P 1.84 e-06, which means that the null hypothesis in this objective, "There is no statistically significant difference in the techniques used to suppress FAW outbreak," is rejected. As a result, the study's conclusion for this goal was that the FAW outbreak was brought under control thanks to the farmers' various measures and the Ministry of Agriculture, Water, and Land Reform's assistance. This helped to a considerable extent to ensure that farmers did not completely lose all their harvests.

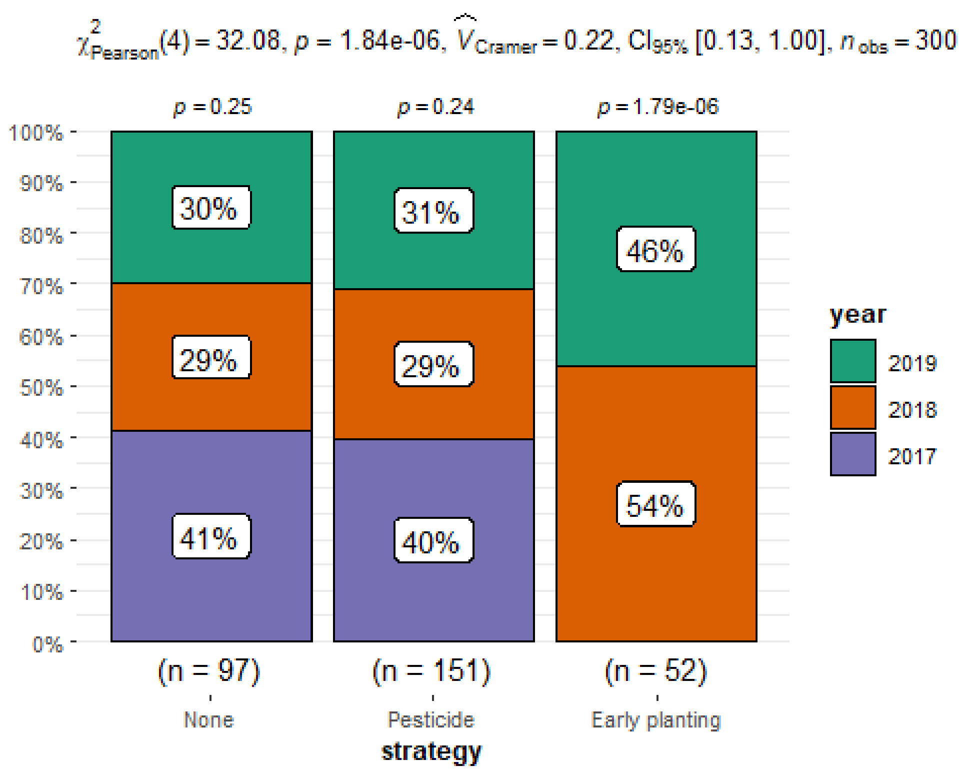

Figure 12: Control methods used to control the FAW outbreak over three seasons

Figure 12 above indicates that 41% of the respondents did not take any action to mitigate the outbreak of FAW in the first season, this might have been caused by the lack of experience because farmers did not have a clue of what this pest was all about, or they did not have means to use to control the FAW outbreak. In the second cropping season, 29% also took no action and in third cropping season 30% of the respondents took no action, this could mean that either they did not experience the outbreak in the latter cropping season or did not consider the FAW outbreak as threat to them. However, the study found out that 40% used pesticide in the first cropping season and 20% in the second season and lastly, 31% in the last season. This is a clear indication that below half of the interviewed respondents used pesticides to control the FAW over the three cropping seasons. The study indicates that majority of the farmers used early planting strategy in the second and third cropping seasons as a mitigation method to control the outbreak of FAW. This might be the good reason of why some of the farmers took no action because their crops might have grown to a stage where they are not vulnerable to the attack of FAW when the FAW transformed into damaging form in their life cycle. Early planting was not an option in the first cropping season because farmers only experience the outbreak in the first season after they have already planted their seed crops. Therefore, the study conclude that early planting was the mostly used strategies that majority farmers applied to mitigate the outbreak of FAW. The picture bellow was taken in Kavango East region in Namibia, it shows how a trained Agricultural Expert as one of the team that controlled FAW outbreak in the region by spraying infested crop fields with pesticides. It also shows the protective gears and all equipment required during the process of controlling the outbreak using pesticide. The most affected crop was maize, followed by pearl millet in the absence of maize, and grass in the absence of maize and pearl millet. A restriction was set by the Government that no farmer was allowed to use any pesticide to control FAW infestation, rather just report the outbreak to the Ministry of Agriculture, Water and Land Reform. Only well-trained staff members of the ministry were allowed to use the specific pesticide to control the outbreak. Reports were received from farmers across the region.

Figure 13: Trained technical staff member from the MAWLR

Source: MAWLR, 2020

4.3 Hypotheses testing

The Welch's *t*-test indicates that there is a highly statistically significant ($p<.0000115$) difference between the expected and actual yield over three years, we reject the hypotheses because the Welch's *t*-test is significant.

The analysis of severity of FAW in the livelihood of farmers with chi-square test indicates that there is a statistical significance difference amongst farmers who experienced the outbreak and those who did not with $P<.1.98e\text{-}72$ prompting the study to reject the null hypothesis.

The analysis of strategies used by farmers during the outbreak of FAW with chi-square indicates that there is statistical significance difference amongst farmers who experienced the outbreak and those who did not with *P 1.84 e-06* prompting the study to reject the null hypothesis.

4.4 Summary

The study's findings, which investigated the impact of 2016/17 Fall Armyworm outbreak on pearl millet yields in Kavango East region of Namibia, were reported in the chapter. The findings also indicated that the FAW outbreak influenced the production of pearl millet, which influenced the yields and ways of lives of farmers who heavily relied on pearl millet as a staple diet. The research investigation is concluded in the following chapter, which also offers suggestions for future actions.

Chapter 5: Conclusion and Recommendations

5.1 Introduction

This study was meant to determine the impact of Fall Armyworm outbreak on crop harvest during 2016/2017 to 2018/2019 cropping seasons. The study was done through a primary data collection that was done through a survey. This chapter is devoted to concluding the findings of the study and provide policy recommendation about the outbreak of FAW.

5.2 Conclusions

The findings of this study are given in accordance with its objectives. The investigation concluded that FAW has a negative impact on actual yield when compared to expected yield. Farmers' ability to make a living was impacted as a result. Farmers were impacted in two-folds: first fold, the outbreak's destruction prevented farmers from getting the intended output, which had unfavourable effects because it exposed farmers to food insecurity. Second fold farmers could not earn income from marketing pearl millet as they did not excess yield as they usually obtain. As a result, they could only obtain a little yield that was not even sufficient for domestic consumption.

The FAW outbreak seriously impacted the region's farmers' ability to conduct their routine business since it altered how they lived. Fishing provided a chance for those who lived close to the river to establish their livelihoods, but it was exceedingly challenging for those who lived farther away to make ends meet.

The investigation concluded that farmers did their hardest to manage the FAW outbreak by utilizing a variety of techniques/methods. Most farmers employed the early planting technique. This was the case because farmers were aware of when the outbreak occurred the previous season, and as a result, they made strong plans to make their crop develop more quickly with the arrival of rain to avoid the susceptible stage when FAW transition from a larva to a worm. Farmers employ this as a mitigation approach if crops are grown past the vulnerable phases to avoid having their crop damaged by FAW.

Pesticides were also utilized as a mitigating technique, although their usage was only permitted under careful supervision by representatives of the Ministry of Agriculture, Water, and Land Reform. Farmers were not permitted to handle the herbicide due to its chemical nature. Therefore, those who claimed to have used it did so with the help of Ministry representatives.

5.3 Recommendations

National Disaster Risk Management should:

- Monitor FAW crop loss and control measures to give evidence for national decisions;
- Ensure that the voices of all stakeholders, especially smallholder farmers, are heard;
- Apply any subsidies to promote the use of low-risk control strategies;
- Learn from the tracking of FAW outbreak so it can be applied to that other outbreaks can benefit.

Technical Advisory Services should:

- Agricultural Technicians in the Kavango East region and other areas of Namibia, the Ministry of Agriculture, Water, and Land Reform to continuously train farmers on low-cost pest management methods, such as early planting and crop rotation;
- Agricultural Technicians - Ministry of Agriculture, Water, and Land Reform in Namibia should encourage farmers to diversify their crop cultivation by considering alternative cash crops that are not or are very minimally affected by FAW in the Kavango East region. If FAW spreads, having other alternative sources of revenue from other cash crops farmed by farmers helps to stabilize income;
- Agricultural Technicians to encourage farmers to:
    1. Avoid practices which kill natural enemies of FAW
    2. Observe and monitor fields regularly after germination
    3. Experiment with different control practices
    4. Refrain from intervening as soon as leaf damage is observed

Regulatory body should:

- Maintain regulatory credibility by providing emergency/temporary registration for government-recommended products;
- Work with industry associations to identify and stop companies selling unregistered and/or dangerous products;
- Within the existing framework, expedite registration of lower risk products;
- Continue efforts to regionally harmonise pest control product regulations.

5.4 Recommendations for future research

- Similar research to be expanded to other parts of Namibia where pearl millet is a major source of revenue and staple food;
- Further research is strongly advised that considers other variable elements of pearl millet productivity, such as rainfall variability, soil fertility, and financial inputs like fertilizers, in addition to the effect of FAW on output of pearl millet and farmers' income;
- Scientific study to be conducted on the morphology of FAW to comprehend how these worms reproduce and how to stop their reproduction to stop wreaking havoc on the life of rural farmers and other people;
- Continue research on the use of host plant resistance and classical biological control;
- Continue research on FAW biology and ecology, with the aim of improving control decisions by farmers and other stakeholders;
- When developing and introducing new control practices, consider efficacy, safety, sustainability, practically, availability and cost effectiveness for smallholder farmers;
- Test and validate control methods commonly used by farmers;
- Develop simple and robust action thresholds based on the FAW damage levels;
- Determine why recommended control actions are sometimes not effective;
- Monitor FAW natural enemies and identify practices that conserve and enhance the mortality they cause;
- Identify opportunities for establishing local enterprises producing bio-inputs.

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Appendices

Appendix 1: Field Sheet for Data Collection

THE IMPACT OF 2016/17 FALL ARMYWORM OUTBREAK ON PEARL MILLET YIELD IN NAMIBIA

QUESTIONNAIRE SEPTEMBER 2020

Declaration of confidentiality and anonymity to the participants

I am a Master of Agribusiness Management student at the Namibia University of Science and Technology. I am conducting research on a topic: ***Investigating direct economic impact caused by Fall Armyworm outbreak in Namibia during 2016/2017 season. Kindly provide me with the necessary information that is required to complete this study.*** The study will only include farmers that have experienced the outbreak of Fall Armyworm. Information that you will provide shall be treated with a high degree of confidentiality and shall only be used for academic purposes. Anonymity is highly guaranteed for the protection of your views and opinions.

SECTION A: QUESTIONNAIRE INFORMATION

Name of interviewer(s)	
Date of interview	
Location of household/farm	
• Region	
• Constituency	
• Village	
• GPS coordinates home	S E (decimal degrees)
• GPS coordinates farm plot/field	S E (decimal degrees)
Language spoken during interview	
Time of interview	[:] to [:]

SECTION B: PERSONAL INFORMATION

B1. Gender of the farmer:

Male	

B2. Relationship of the farmer to the household head

Owner	

Female	

Spouse	
Son	
Daughter	
Other (specify)	

B3. Farmer's age

B4. Activities at the farm

Crop Production	
Animal Production	
Mixed Farming	

B5. Household size

Number of children < indicate age range	
Number of adults age range	
Number of elderly > age range	

B6. Farmer's education level attained. (Indicate with a tick where appropriate)

Code	Qualification	Option
1	No formal education	
2	Primary school	
3	Secondary education	
4	Tertiary education	

B7. Years of farming experience? | Years |

SECTION C: FALL ARMYWORM INCIDENCE AND OUTPUT

C1. What direct impact did the Fall Armyworm outbreak brought on your yields as a farmer?

Crops grown in 2016/2017 summer season	**Expected Output**	**Actual Output**	**Hectares planted**
i)			
ii)			
iii)			
Crops grown in 2017/2018 summer season			
i)			
ii)			
iii)			
Crops grown in 2018/2019 summer season			
i)			
ii)			
iii)			

C2. How was the severity of Fall Armyworm outbreak during the following summer seasons?

	None	**Mild**	**Severe**	**Very severe**
2016/2017				
2017/2018				
2018/2019				

Where do you get seed from…………………………………………………………………………….?

Do you use fertilizer…………………………………………………………………………………….?

If yes, how much fertilizer did you apply in each of the seasons…………………………………….?

If no, what do you use to enhance the fertility of your soils…………………………………………?

C3. Which methods did you use to prevent/control Fall Armyworm and other pests in the years?

	Early Planting	Pesticides	None	Other: Please Specify
2016/2017				
2017/2018				
2018/2019				

C4. How is your livelihood affected by Fall Armyworm outbreaks? (Indicate with a tick where appropriate)

	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
It reduced crop yield					
It reduced quality of the crop					
Loss of income					
It affected livelihood					
Loss of food					

C5. Are they any other factors that affected your output other than the Fall Armyworm outbreak?

____

____

____

____

____

C6. Did you sale your produce?

Cropping seasons:	Indicate type of produce sold:
2016/2017	
	i)
	ii)
	iii)
2017/2018	
	i)
	ii)

	iii)
2018/2019	
	i)
	ii)
	iii)

C7. Comments/remarks

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Thank you for your time

Appendix 2: Anova Tables

Anova 1

	df	SS	MS	F	Significance F
exp_act	1	38.4	38.44	32.73	1.68e-08
Residuals	598	702.4	1.17		
Total	599				

Anova 2

	df	SS	MS	F	Significance F
exp_act	1	36.02	36.02	32.03	5.28e-08
Residuals	198	222.68	1.12		
Total	199				

Anova 3

	df	SS	MS	F	Significance F
exp_act	1	9.28	9.278	8.572	0.00381
Residuals	198	214.30	1.082		
Total	199				

Anova 4

	df	SS	MS	F	Significance F
exp_act	1	2.86	2.859	2.685	0.103
Residuals	198	210.82	1.065		
Total	199				

Anova 5

	df	SS	MS	F	Significance F
exp_act	2	45.2	22.619	18.59	2.46e-08
Residuals	297	361.3	1.216		
Total	299				

Appendix 3: Certificate of editing

BUSINESS AND EDUCATION DEVELOPMENT CONSULTANCY CC

(Building the economy through Business Consultancy, Education and Training)

7373 Elephant Street
Rhino Park
Windhoek
email: bedccc@gmail.com

P. O. Box 25246
Windhoek
Phone: 061 400735
0812082908

19 August 2022

CERTIFICATE OF EDITING

This document certifies that the thesis on "Investigating direct economic impact caused by fall armyworm outbreak in Namibia during 2016/2017 season" authored by Lynnety Chaze Sinalumbu was edited for English language, grammar, punctuation, spelling and general formatting style by BUSINESS AND EDUCATION DEVELOPMENT CONSULTANCY.

The editors take no responsibility of any technical formatting on this document or any changes made at a later stage.

Chikarango, T.
(Chief Editor)