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Outbreaks of the Fall Armyworm (*Spodoptera frugiperda*), and Maize Production Constraints in Zambia with Special Emphasis on Coping Strategies

Chapwa Kasoma [1,2,*], Hussein Shimelis [1], Mark D. Laing [1], Admire Shayanowako [1] and Isack Mathew [1]

1 African Centre for Crop Improvement, School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, Scottsville, Pietermaritzburg 3209, South Africa; Shimelish@ukzn.ac.za (H.S.); Laing@ukzn.ac.za (M.D.L.); shayanowako@gmail.com (A.S.); isackmathew@gmail.com (I.M.)
2 Zambia Agricultural Research Institute, Lusaka Private Bag 7, Zambia
* Correspondence: chapwak@gmail.com

Abstract: The fall armyworm (FAW) (*Spodoptera frugiperda* J.E. Smith) is an invasive pest of maize, as well as other important cereals and vegetables, threatening food systems and biodiversity in Sub-Saharan Africa. This study aimed to assess the outbreaks of the FAW, farmers' perceived production constraints, and coping strategies in maize production in Zambia. A participatory rural appraisal (PRA) study was conducted in two FAW-affected maize production districts in Zambia in 2017 and 2018. Data were collected using semi-structured questionnaires, preference ranking, and focused group discussions. Crop losses due to FAW, the high cost of fertilizers, and a limited availability of arable land were the major production constraints across the districts. There were significant differences (X^2 = 12.415; p = 0.002) in the severity of FAW infestation between the two districts in 2017. Notable FAW coping strategies used by the respondent farmers included cultural and landscape management practices, chemical pesticides, and crushing of FAW larvae. There was a disparity between male and female respondents who perceived social, agronomic management, and crop protection-related factors that influenced the choice of a maize variety. Information presented here will serve as a basis for FAW-resistant cultivar development and deployment of the integrated pest management methods for Zambia.

Keywords: cultivar development; FAW; farmer preferences; invasive pest; participatory rural appraisal

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Citation: Kasoma, C.; Shimelis, H.; Laing, M.; Shayanowako, A.; Mathew, I. Outbreaks of the Fall Armyworm (*Spodoptera frugiperda*), and Maize Production Constraints in Zambia with Special Emphasis on Coping Strategies. *Sustainability* **2021**, *13*, 10771. https://doi.org/10.3390/su131910771

Academic Editor: Riccardo Testa

Received: 2 August 2021
Accepted: 20 September 2021
Published: 28 September 2021

1. Introduction

The fall armyworm (FAW) (*Spodoptera frugiperda* J.E. Smith (Lepidoptera: Noctuidae)) is a relatively new, polyphagous pest affecting cereal crops in Africa. The combination of FAW together with existing production constraints have threatened the stability and sustainability of food systems, livelihoods, ecosystems biodiversity, local, regional, and global trade in Sub-Saharan Africa (SSA) since its arrival in 2016 [1]. The FAW originated from the tropical and subtropical regions of South America, where it is a major migratory pest. The pest has a devastating impact on maize yields. [2]. In SSA, the FAW has become a resident pest owing to the favorable environmental conditions and the presence of host plants [3,4].

Maize (*Zea mays* L., 2n = 2x = 20) is the main staple food for more than 500 million people in SSA [5]. It is mainly cultivated by small-scale farmers using low input production systems [6]. Most farming systems in SSA are prone to major crop production constraints including biotic stressors (diseases and insect pests), abiotic stressors (drought stress and low soil fertility) and various socio-economic constraints such as inadequate extension services and poor access to credit opportunities. Consequently, the present mean yield of maize in SSA, including Zambia, stands at 2.1 t ha^{-1}, relative to the potential yield of 10 t ha^{-1} [7–9].

Maize is a staple and commodity crop in Zambia where the area of production has generally increased since the early 1960s [10]. Nonetheless, the yield of the crop is low and stagnant because of multiple challenges including a lack of improved cultivars, prevalence of pests and diseases, few integrated pest management (IPM) options for crop protection, recurrent droughts, lack of technology, poor crop management practices, and high costs of pesticides and fertilizers. The emergence of FAW in 2016 exacerbated the present maize production challenges affecting food security in SSA, including Zambia [2]. FAW has been reported in 45 African countries [11]. The FAW was first detected in Zambia in December 2016, and it spread quickly across the entire country, covering all 10 provinces by January 2018 [12,13]. Maize is a favored host crop for FAW, resulting in yield losses of between 21 and 53% in SSA, depending on the severity of FAW attack, cultivar susceptibility, the farming system and management practices [14]. The continent requires FAW resistant maize varieties to augment IPM strategies that include biological, chemical, and cultural control strategies to manage the FAW pest.

Assessing the present FAW outbreak and prioritizing the prevailing farmers' maize production constraints, coping mechanisms, and trait preference of a maize variety is an overriding consideration. This will guide the breeding and deployment of FAW resistant and farmer-preferred cultivars. There is a paucity of published information on the current maize production constraints and their interactions since the outbreak of the FAW. Moreover, FAW coping mechanisms presently adopted by farmers in Zambia and elsewhere in Africa are not well documented for the development of innovative crop protection measures integrating farmers' knowledge, needs, and preferences.

Participatory rural appraisal (PRA) is a multi-disciplinary research approach widely used to document farmers' production constraints and their coping strategies, and trait preferences in new varieties emerging from pre-breeding and breeding programs [15]. PRA tools have been widely used to gather important data on production and productivity issues. It serves as the first step of market research for crop breeding programs [16–18]. PRAs are regarded as bottom-up, fast-evolving family of methods that enable sharing, enhancing and analyzing farmers' knowledge, and the state of their agricultural livelihoods, for the purpose of planning and action-oriented research [19]. Incorporating gender-related factors in PRA methods further enhances the value and applicability of the information obtained [20]. Mukanga et al. [17] used PRA methods to investigate farmers' perceptions on maize ear rot disease and their implications on breeding for host plant resistance in Zambia. This was the only recent report available in the country employing PRA methodologies. To the best of our current knowledge, there is no study that simultaneously assessed FAW outbreaks, other current farmers' maize production constraints, coping mechanisms, and trait preferences of a maize variety to guide breeding in SSA. Therefore, the objectives of this study were to assess the occurrence and impact of FAW, farmers' perceived production constraints, and coping strategies in maize production in Zambia, to guide cultivar development and the deployment of integrated pest management strategies.

2. Materials and Methods

2.1. Description of the Study Sites

The current study was conducted over two years in the Central and Lusaka provinces of Zambia, which are in agro-ecological Region II (Figure 1). The mean annual rainfall in agroecological region II is between 800 and 1000 mm with the main rain season falling between November and April. Maize is the major crop produced in this region. The region was severely affected by FAW since the 2016 cropping season [17]. Moderately fertile soils with low incidences of nutrient leaching are widely distributed in this region.

Figure 1. A Map of Zambia showing the study areas highlighted by the black dots.

2.2. Sampling Procedure

The study sites and participating farmers were sampled using a purposive sampling procedure in partnership with extension officers from the District Agricultural Coordinating Offices of the Ministry of Agriculture in Zambia. Farmers who were involved in maize production and whose fields were severely affected by FAW in 2016 and 2017 were targeted for the study. For this study, severely affected famers were defined as those farmers whose average maize yield in 2016/2017 season was 50% or less compared to the 2014/2015 season's yield. This was determined based on secondary information provided by the farmers and extension office. Two provinces, i.e., Central and Lusaka were sampled, and the Chibombo and Chongwe districts were sub-sampled, respectively (Table 1 and Figure 1). Furthermore, four camps situated in the two districts were sub-sub-sampled (Table 1). The camps included Nanswisa and Chititi (Chibombo District), and Chainda and Chalimbana (Chongwe District). In each of the selected camps, three villages were sampled, providing a total of 12 sampled villages for the study. In each village 10 to 11 and 8 to 9 farmers were selected for face-to-face questionnaire interviews and focused group discussions (FGDs), respectively (Table 1). The total number of farmers involved for interviews were 121. In addition, four focus groups were established, each with 25 farmers from the three sampled villages. This provided 100 farmers for the FGDs as summarized in Table 1.

2.3. Data Collection

The study involved various stakeholders who played different roles prior to the data collection process. A plant breeder, a crop scientist, and a social scientist were involved in designing the study and questionnaire to ensure that relevant data would be collected. Two senior agricultural research officers were responsible for ensuring that the study was compliant with ethical regulations in Chibombo and Chongwe districts. The two camp heads from each district were responsible for community engagement within their jurisdictions. The questionnaires were administered by four enumerators for data collection. The enumerators received training prior to data collection to reduce collector bias. A pre-test was conducted on a few farmers to fine tune the questionnaire and estimate collector bias. Both qualitative and quantitative data were collected during the study. Data collected in the semi-structured questionnaire, which incorporated both closed and open-ended questions aimed to capture a wider range of qualitative and quantitative responses. The data included farmers' perception of the prevalence and magnitude of FAW damage during the 2016 and 2017 cropping seasons, characteristics of maize production systems with implications on FAW impact, farmers constraints affecting maize production, and farmers' trait preferences in a maize variety. In addition, data were collected about each farmer: gender, age, socio-economic status, educational level, and household income.

Table 1. Sampled provinces, districts, camps, and villages and corresponding farmers for the study.

Province	District	Camp	Village	Sampled Number of Farmers		Focus Group
				Interviewees	FGD	
Lusaka	Chongwe	Chainda	Mukunya	10	8	1
			Chimbali	10	8	
			Ngango	10	9	
		Chalimbana	Kabeleka	10	8	2
			Shishko	10	9	
			Mwampikanya	10	8	
Chongwe	Chibombo	Nanswisa	Njema	10	9	3
			Nkwashi	11	8	
			Makusa	10	8	
		Chititi	Kalusa	10	8	4
			Musopela A	10	9	
			Musopela B	10	8	
Total				121	100	

Note: FGD = focused group discussion.

Further data were collected through four transect walks. Data collected during the transect walks were mainly through field observations and included information on the cropping calendar, the type of cropping systems in the surveyed areas, and the extent of FAW damage in farmers' fields. Each transect walk combined farmers from villages of close proximity to each other within a camp and involved women, men and youth.

Furthermore, four FGDs were undertaken involving situational analyses and preference ranking, which are participatory methods designed to capture farmers' production circumstances and preferences. The FGDs were disaggregated by demographics in that discussion questions within each of the four focus groups were tackled on the basis of the age and gender of the respondents, to ensure equal participation and representation of all farmers.

2.4. Data Analysis

The collected qualitative data were coded and categorized using numeric values. Farmers' perception of FAW damage was coded 1 or 2, corresponding to present or absent, respectively. Similar coding patterns were used for the other qualitative parameters including, current maize production constraints and trait preferences prior to data analysis. SPSS version 24 was used to analyze the counts, frequencies, percentages and Chi-square values [21]. Descriptive statistics were deduced, while pair-wise comparisons between groups of respondents were cross-tabulated and subjected to the Pearson Chi-square test statistic procedure to deduce trends and validate their significance for decision-making. Factors influencing maize trait preferences that were reported by the farmers were assigned numeric codes from 1 to 12 and analyzed separately for male and female respondent farmers using principal component analysis following a dimension reduction procedure employing a correlation matrix using the SPSS. The major trends emanating from qualitative data obtained during the FGDs were used to substantiate the quantitative data obtained from the questionnaires.

3. Results

3.1. Socio Demographic Characteristics of Respondent Farmers in the Surveyed FAW Affected Districts during the 2016–2017 Cropping Season

The number of male and female farmers who reported the presence of FAW damage in their maize fields did not differ significantly between the Chibombo and Chongwe districts (X^2 = 0.002; p = 0.962) (Table 2) due to widespread field infestation by the pest. There were significant differences in age (X^2 = 22.56; p = 0.000) and family sizes (X^2= 9.953; p = 0.007) of the respondent farmers within and between the two districts. The respondents were aged between 15 and 70 years old and their family sizes ranged from 1 to 15 family members per household. The level of education of respondents between the two districts did not differ significantly (X^2 = 0.003; p = 0.768). The majority of the respondent farmers in both districts had attained primary education. Differences in household income of respondents between Chibombo and Chongwe were non-significant (X^2 = 0.005; p = 0.562), with most farmers earning between Zambian Kwacha (ZMW) 3000 to 5000 annually. Seventy percent of the sampled households owned agricultural lands ranging between 1 to 5 hectares (Table 2). However, farm sizes varied across the study districts, with more farmers in Chongwe owning farms of between 6 and 15 hectares. A small proportion (8.4%) of the respondents in Chibombo did not own land but either rented or shared lands with other farmers.

Table 2. Socio-demographic profile of respondent farmers (%) in the Chibombo and Chongwe districts during the study (N = 121).

Variable	Class	Chibombo	Chongwe	Chi-Square	Df	*p*-Value
Gender	Male	31.7	30.8	0.002	1	0.962
	Female	19.2	18.3			
Age (years)	15–30	19.1	1.7	22.560	3	0.000
	31–50	20.0	19.1			
	51–70	11.3	20.9			
	>70	1.7	6.1			
	Zero	6.4	5.9			
Educational level	Primary	21.3	27.2	0.003	3	0.786
	Secondary	14.3	11.5			
	Tertiary	8.0	5.6			
Family size (number)	<5	16.4	4.3	9.953	2	0.007
	5–10	31.0	38.8			
	>10	3.4	6.0			
Household income (ZMW)	<1000	3.6	5.2	0.005	3	0.562
	1000–3000	17.4	19.3			
	3000–5000	18.5	15.7			
	>5000	10.5	9.9			
Land owned (ha)	0.0	8.4	0.0	14.706	5	0.012
	<1	2.5	0.8			
	1–5	34.5	37			
	6–10	4.2	8.4			
	11–15	0.8	2.5			
	16–20	0.8	0.0			

Note: df, degrees of freedom; primary and secondary education refer to grades 1 to 7 and 8 to 12, respectively, while tertiary education refers to a college certificate/diploma or university degree; ZMW, Zambian Kwacha (1 USD = 22.29 ZMW per current exchange rate).

3.2. Frequency and Severity of FAW Occurrence in the Chibombo and Chongwe Districts in Zambia

All the interviewed farmers in Chibombo and Chongwe reported the occurrence of FAW in their maize fields in at least one crop season during 2016–2017 and 2017–2018 (Table 3). There were significant differences (X^2 = 12.415; p = 0.002) in the severity of FAW infestation between the districts for one season's occurrence of the pest. However, the severity did not differ significantly (X^2 = 4.469; p = 0.298) for multiple season's infestations, including both the main and off-seasons due to heavy infestations. Based on a single season's infestation by FAW, 58.3% respondent farmers reported moderate damage to their maize fields, while 79% of respondents experienced multiple infestations and reported severe crop damage and yield loss.

Table 3. Occurrence and severity of FAW in the study areas.

Frequency of FAW Occurrence	Level of Damage	District		Total	Chi-Square	Df	*p*-Value
		Chibombo	Chongwe				
Occurred in one season (main season)	SD	13.9	1.4	15.3	12.415	2	0.002
	MOD	34.7	23.6	58.3			
	MID	6.9	19.4	26.4			
Occurred in two seasons (main and off seasons)	SD	33.3	46.2	79.5	1.082	1	0.298 ns
	MOD	12.8	7.7	20.5			

Df, degrees of freedom; *p*-value, probability value, ns, non-significant; SD, severe damage; MOD, moderate damage; MID, mild damage.

3.3. Farmers' Perceptions of FAW Damage Symptoms, Severity and Associated Yield Losses

Table 4 presents FAW damage symptoms, severity, and associated yield losses as perceived by farmers in the study districts. There were highly significant differences (X^2 = 17.626, p = 0.001) in FAW damage symptoms reported by farmers in the two districts, whose maize fields were severely damaged by the FAW (Table 4). About 61% of the respondent farmers observed substantial crop leaf damage, while 19.5% reported grain deformation as the most common symptoms of FAW damage on maize. These farmers estimated that yield loss due to severe damage by FAW was above 50%. For farmers whose maize field experienced moderate and mild FAW damage, the observed damage symptoms were similar.

Table 4. Level of FAW damage, associated symptoms and estimated yield loss in maize as reported by the respondent farmers in Chibombo and Chongwe districts.

Level of Damage	Estimated Yield Loss	Symptom	Districts		Total (%)	Chi-Square	Df	*p*-Value
			Chibombo (%)	Chongwe (%)				
Severe	>50%	Leaf color change	9.8	2.4	12.2	17.626	4	0.001
		Perforated leaf	0.0	2.4	2.4			
		Big leaf portions eaten away	17.1	43.9	61.0			
		Grain deformation	24.4	0.0	24.4			
Moderate	20–49%	Leaf color change	38.0	30.0	68.0	7.145	3	0.067 ns
		Multiple holes in leaf	0.0	2.0	2.0			
		Big leaf portions eaten away	8.0	6.0	14.0			
		Grain deformation	16.0	0.0	16.0			
Mild	<20%	Leaf color change	15.0	60.0	75.0	3.81	3	0.283 ns
		Perforated leaf	5.0	0.0	5.0			
		Big leaf portions eaten away	5.0	5.0	10.0			
		Grain deformation	5.0	5.0	10.0			
Total		Leaf color change	23.4	25.2	48.6	22.057	5	0.001
		Perforated leaf	0.9	0.0	0.9			
		Multiple holes in leaf	0.0	1.8	1.8			
		Big leaf portions eaten away	10.8	19.8	30.6			
		Grain deformation	17.1	0.9	18.0			

Note: Df, degrees of freedom; ns, not significant; *p*-value, probability value.

The most common damage symptom under moderate and mild FAW damage was leaf color change, which was reported by 68 and 75% of farmers, respectively. Grain deformation was reported by 16% of the farmers under moderate FAW damage and 10% under mild FAW damage. The recorded FAW damage symptoms were highly significantly different among the respondent farmers in the three categories of FAW damage level (X^2 = 22.057, p = 0.001). Overall, respondent farmers described leaf color change and 'big leaf portions eaten away' as the most observed symptoms reported by 48 and 30.6% of respondents, respectively. Figure 2 shows a typical FAW damaged maize crop in Ngango village of the Chongwe District in February 2018. This was observed during a transect walk with local farmers and the research group. The crop showed severe injury of leaves, deep holes in the stalks, and reduced silk lengths and quantity due to FAW feeding.

Figure 2. A maize crop damaged by FAW in Ngango Village of the Chongwe district in Zambia. Note the highly perforated and damaged leaves, reduced plant height, and poor silk development of the maize cobs that were typical symptoms. (Photo by Chapwa Kasoma).

3.4. Farmers' Knowledge of Potential Control Methods against FAW in the Chibombo and Chongwe Districts

Farmers reported using several control methods against FAW in maize. The main farmer practices to control FAW in the study areas included application of sand/ash/lime in maize leaf whorls (reported by 28% of the farmers), spraying with chemical pesticides (25%), field scouting, and the picking and crushing of FAW larvae by hand (21%). The farmers who used sand/ash/lime, scouted their fields, picked and crushed FAW larvae indicated that if used consistently, the methods were considerably effective in reducing FAW populations in their maize fields and minimizing crop damage. They did not, however, indicate the impact of using these methods on maize yield. Chemical pesticides were reported as effective but expensive because more than a single spray was required to adequately control the recurring FAW populations in their maize fields. Additional methods include clearing the field from weeds (11%), smoking of the field (3%) and the use of resistant landrace varieties (2.7%), although farmers did not indicate the level of effectiveness of these methods in reducing FAW population, crop damage or yield. Some farmers (5%) reported the use of some unclassified methods including the application of fertilizer granules into leaf whorls and the spraying of a sugar solution onto maize plants to attract natural enemies of FAW, which they perceived as effective in reducing pest populations. A small proportion of the respondent farmers (3%) indicated that they were unaware of any effective methods to control FAW and that they had abandoned their maize crops.

3.5. Maize Production Systems and Implications on FAW Management in the Chibombo and Chongwe Districts

The overall mean production area devoted to maize per household in the study districts was 1.75 ha. The highest mean area under maize production per respondent farmer was 2.07 ha, recorded in the Chainda camp (Chongwe District), while the lowest mean value of 1.33 ha was recorded in the Chalimbana camp (Chongwe District). Respondent farmers in the Chongwe District practiced intercropping of maize with legumes, including groundnut (*Arachis hypogaea* L.) and cowpea (*Vigna unguiculata* Walp.), while farmers in Chibombo used sole cropping of maize. In the Chongwe district, a total of 87.5 % respondents (44.6 and 42.9 % for the Chainda and Chalimbana camps, respectively) acquired seed from farmer cooperatives. Only farmers in Chibombo's Nanswisa camp obtained seed from the Zambia Agricultural Research Institute (ZARI). The majority of respondents (56.6%) in Chibombo's Nanswisa camp sourced their maize seed from agro-dealers. Respondent farmers in the Chibombo and Chongwe districts reported that during 2014 to 2017, their maize yields ranged approximately between 2.12 and 3.14 t ha $^{-1}$ (Table 5). The average yield of maize obtained in the four-year period corresponded with the area allocated to maize production. The Chibombo district had a larger area under maize cultivation and had higher maize yields than the Chongwe district.

Table 5. Maize production systems in Chibombo and Chongwe districts in Zambia.

Camp/District	Production Area	Cropping System		Main Source of Seed			Use of Fertilizers and Crop Rotation		Yield (tons/ha) (Mean ± SD)
	Cultivated Area per Household during 2014 to 2017 (ha) (Mean ± SD)	Sole Crop (%)	Intercrop (%)	Cooperatives (%)	ZARI (%)	Agro-Dealers (%)	Inorganic Fertilizers (%)	Crop Rotation	
Camp									
Nanswisa	1.90 ± 1.87	100.0	0.0	1.2	63.1	35.7	26.3	28.8	3.14 ± 4.23
Chititi	1.73 ± 1.89	100.0	0.0	65.6	0.0	34.4	29.5	16.3	2.89 ± 3.43
Chainda	2.07 ± 0.83	25.4	79.8	72.8	0.0	27.2	16.8	26.0	3.05 ± 2.09
Chalimbana	1.33 ± 0.82	34.8	65.2	65.9	0.0	34.1	27.4	28.8	2.12 ± 2.76
District									
Chibombo	1.82 ± 1.87								3.02 ± 3.83
Chongwe	1.69 ± 0.90								2.57 ± 2.48
Mean	1.75								2.80

Note: SD = standard deviation; ZARI, Zambia Agricultural Research Institute.

3.6. Other Major Constraints to Maize Production in the Study Areas

During the interviews, respondent farmers described 12 major constraints affecting maize production that were perceived to influence crop yield and FAW management practices (Table 6). The high cost of fertilizer was ranked by 73% of the respondent farmers as the most important constraint to maize production. The second most important constraint perceived to exacerbate FAW-related maize yield loss was attack from other insect pests as opportunistic and secondary pests. Farmers indicated that the most challenging additional insect pests were weevils during storage, and termites and stalk borers in the field. Limited agricultural land was identified as the third most important constraint in the two districts. Other notable production constraints in the surveyed areas included drought stress (36.6%), poor soil fertility (28.6%) and a lack of essential quality traits in newly released maize varieties (7.7%). Most farmers classified poor soil fertility (42.9%) as a constraint of intermediate importance. A lack of suitable maize varieties with desirable traits was considered to be of intermediate importance by 69.2% of the farmers. This parameter was given an overall ranking of 10 in the two surveyed districts (Table 6).

3.7. Farmer's Trait Preferences in Maize

Farmers listed and ranked several traits that they preferred in a maize variety. Several of the listed traits perceived by the farmers to have direct potential for FAW management and mitigation of crop damage were indicated during the FGDs and interviews (Table 7). Trait preferences showed highly significant differences between the two districts (X^2 = 33.8; p = 0.000). These differences were associated with maize production, marketing and consumption. About 57 and 42% of the respondents ranked high yield as the most important and preferred trait from Chibombo and Chongwe, respectively. In the Chibombo district, insect pest resistance was ranked by 64% of respondents as the second highly preferred trait after disease resistance. In contrast, in the Chongwe district, drought tolerance, and suitability for intercropping were considered essential traits of a maize variety by 65 and 58% of the respondent farmers, respectively. Other farmer-valued traits included low aflatoxin accumulation and good market demand. These traits were ranked highly by the farmers in the Chibombo district. Processing quality, early maturity and environmental adaptability were ranked highly by ≥ 50% of farmers in the Chongwe district.

Table 6. Farmers' maize production constraints in the Chibombo and Chongwe districts in Zambia.

Constraint	Proportion of Farmers (%) Ranking This Constraint (Rank)	Level of Importance	Chibombo (%)	Chongwe (%)	Total (%)	Chi-Square	Df	*p*-Value
Limited agriculture land	13.5 (3)	VI IM II NI	20.7 23.2 7.3 11.0	6.1 2.4 9.8 19.5	26.8 25.6 17.1 30.5	41.167	3	0.0
Poor soil fertility	9.2 (5)	VI IM II NI	14.3 26.8 10.7 10.7	14.3 16.1 3.6 3.6	28.6 42.9 14.3 14.3	17.685	3	0.039
Low-yielding varieties	4.0 (9)	VI IM II NI	0.0 27.8 16.7 5.6	5.6 33.3 0.0 11.1	5.6 61.1 16.7 16.7	5.056	3	0.537
Limited access to improved varieties	4.2 (8)	VI IM II NI	5.3 5.3 21.1 15.8	0.0 10.5 10.5 31.6	5.3 15.8 31.6 47.4	10.556	3	0.307
New varieties lacking suitable traits	3.1 (10)	VI IM II NI	7.7 0.0 7.7 7.7	0.0 0.0 61.5 15.4	7.7 0.0 69.2 23.1	4.494	3	0.343
A lack of improved seed	6.0 (7)	VI IM II NI	6.7 10.0 6.7 10.0	0.0 16.7 40.0 10.0	6.7 26.7 46.7 20.0	16.815	3	0.052
High cost of fertilizers	17.0 (1)	VI IM II NI	35.0 6.8 3.9 0.0	37.9 16.5 0.0 0.0	72.8 23.3 3.9 0.0	19.86	3	0.019
Limited access to fertilizer	6.1 (6)	VI IM II NI	22.6 29.0 12.9 3.2	3.2 25.8 3.2 0.0	25.8 54.8 16.1 3.2	41.361	3	0
Drought stress	11.7 (4)	VI IM II NI	7.0 1.4 18.3 16.9	29.6 1.4 22.5 2.8	36.6 2.8 40.8 19.7	35.515	3	0
Insect pests	15.2 (2)	VI IM II NI	19.6 5.4 7.6 8.7	18.5 21.6 3.3 10.9	38.0 31.5 10.9 19.4	28.287	3	0.001
Diseases	6.0 (7)	VI IM II NI	3.3 20.0 13.3 10.0	0.0 20.0 6.7 26.7	3.3 40.0 20.0 36.7	22.585	3	0.007
Bird damage	4.0 (9)	VI IM II NI	0.0 0.0 22.2 27.8	11.1 0.0 27.8 11.1	11.1 0.0 50.0 38.9	3.651	3	0.455

Note: df, degrees of freedom; ns, non-significant; VI, very important; IM, important; II, intermediate important; NI, not important.

Table 7. Trait preferences in a maize variety by farmers in Chibombo and Chongwe districts in Zambia.

Trait	District		Chi-Square	Df	*p*-Value
	Chibombo (%)	Chongwe (%)			
High yield	42.3	56.8	33.8	10	0.000
Processing quality	46.0	54.0			
Suitability for intercropping	42.0	58.0			
Early maturity	46.9	53.1			
Drought tolerance	34.5	65.4			
Insect resistance	64.3	35.5			
Disease resistance	75.0	25.0			
Storage pest resistance	52.5	47.5			
Low aflatoxin accumulation	60.0	40.0			
Good market demand	55.5	44.5			
Environmental adaptability	50.0	50.0			

df, degrees of freedom.

3.8. Factors Influencing Farmers Trait Preferences in a Maize Variety

Table 8 summarizes the proportions of social, agronomic, and plant protection factors influencing famers' trait preference of a maize variety or maize production in the study areas. Regarding male respondent farmers, the first six principal components (PCs), with eigen values greater or equal to 1 accounted for 69.57% of the variation in the constraints to maize production. The most influential factors were social, plant protection-related and agronomic factors. Notable factors underlying the differences in maize production constraints included region, family size, extension services, insect pest resistance, and good market price. For the female respondent farmers, the first six PCs accounted for 68.74% of the total variation in their perception of constraints to maize production. Social, agronomic and plant protection-related factors, influenced this variation. The most important factors contributing to the pattern of variation observed among the female respondent farmers in order of importance were region, early maturity, good market price, drought tolerance, cooking quality, and insect pest resistance. Constraints to maize production among both male and female respondent farmers were largely influenced by social factors such as region, extension services and family size. The second and third most influential factors differed between the two genders, with female respondent farmers being more influenced by agronomic than plant protection-related factors, unlike the male respondents.

Table 8. Eigen values, proportions of social, agronomic and plant protection factors influencing famers' trait preferences in a maize variety in Zambia.

	Male						Female					
	PC1	PC2	PC3	PC4	PC5	PC6	PC1	PC2	PC3	PC4	PC5	PC6
Eigen values	3.01	1.80	1.59	1.23	1.11	1.01	2.66	1.92	1.62	1.25	1.15	1.03
Proportion of variation	21.46	12.82	11.33	8.81	7.93	7.21	18.96	13.7	11.55	8.95	8.19	7.38
Cumulative variation	21.46	34.28	45.61	54.42	62.35	69.57	18.96	32.66	44.21	53.16	61.35	68.74
Social												
Region	**0.906**	0.116	−0.019	−0.012	−0.017	−0.139	**0.930**	−0.072	−0.007	0.057	0.139	0.033
Extension service	0.005	**0.649**	−0.214	-0.670	0.305	0.273	0.136	**0.594**	−0.368	−0.114	−0.006	−0.305
Family size	**0.543**	−0.225	−0.142	0.108	0.056	0.349	0.476	0.319	0.135	0.00	−0.395	−0.111
Good market price	0.255	**0.621**	0.296	0.223	0.121	0.309	0.429	**0.611**	0.069	0.04	−0.276	−0.287
Agronomy												
High yield	−0.221	−0.055	0.065	0.590	−0.238	−0.427	-0.206	0.099	0.134	**0.579**	−0.125	0.420
Early maturity	0.376	0.451	0.201	0.282	−0.288	−0.220	**0.506**	0.480	0.103	0.214	−0.086	0.292
Drought tolerance	−0.456	0.381	0.448	−0.001	0.260	−0.119	0.322	**0.608**	0.324	−0.085	0.091	−0.135
Adaptability	0.025	0.078	0.026	−**0.804**	−0.152	−0.194	0.017	−0.006	−0.044	−**0.745**	0.281	0.380
Cooking quality	0.025	0.018	−**0.812**	0.078	0.115	−0.224	−0.029	−0.208	−**0.733**	0.257	0.301	−0.040
Plant protection												
Insect pest resistance	−0.106	−**0.649**	0.571	0.025	0.177	0.131	−0.230	−0.419	−**0.733**	−0.014	−0.067	−0.235
Disease resistance	−0.011	−0.247	−0.219	0.234	−**0.683**	−0.075	−0.219	−0.151	−0.044	0.361	0.380	−**0.455**
Storage pest resistance	−0.339	−0.111	−0.363	0.174	−0.468	**0.537**	−0.384	−0.096	−0.344	0.107	−**0.520**	0.255

PC, principal component; bold faced values denote factors with higher loading scores.

4. Discussion

4.1. Socio Demographic Profile of Farmers

The non-significant differences in the numbers of participating male and female respondent farmers between the Chibombo and Chongwe districts (Table 1) indicated a similarity in the gender-responsiveness of the two districts with regards to maize production practices. Although women play significant roles in maize production, including land preparation, weeding, fertilizer application, harvesting, seed sorting and packaging [22], the men were the ones mostly interviewed as the household heads and the ultimate decision makers on the use of the household resources. Diiro et al. [6] also highlighted that even in male-headed families in Africa, women and children played substantial roles in maize production systems and for this reason, the FGDs and transect walks were structured to include equal numbers of male and female respondent farmers.

4.2. Frequency and Severity of FAW Damage in the Chibombo and Chongwe Districts

Farmers whose fields experienced FAW infestations over two successive cropping seasons reported more severe damage to their maize fields than farmers whose fields were only infested during one season. This trend may be attributed to the latter's limited experience with the FAW pestilence, resulting in an incorrect attribution of FAW damage symptoms to other pests or diseases. The farmers may have failed to see the FAW larvae because the FAW larvae burrow into the leaf-whorl during the day and only come out to feed at night or very early in the morning when most farmers are away from their fields [23]. This observation could be pertinent when FAW infestations occur during the seedling stage, and the FAW damage could be attributed to a stem cutter or stem borer [24]. FAW infestations were reported to be more severe by farmers with more than one season's experience with FAW because the pest established more stable populations by the second season and, therefore, had greater potential to cause severe damage. This assumption is supported by the findings of Rosenzweig et al. [25] that insect populations spawn in successive seasons, increasing the severity of crop damage, especially in warm temperatures. Successive infestations also increased the farmers' ability to distinguish FAW damage from other pests. The non-significant differences in the severity of FAW damage between the two districts recorded for multiple seasons of encounter with the pest suggested that there was a gradual build-up of FAW populations in subsequent seasons, spurred on by favorable environmental conditions and the availability of suitable host plants.

4.3. Farmers' Perceptions of FAW Damage Symptoms, Severity and Associated Yield Losses

A large proportion of farmers reported that big leaf portions were eaten, and estimated FAW- associated yield losses of more than 50% (Table 4). The majority of the farmers were only able to identify FAW field infestations when it was too late to take any protective action. None of the farmers could identify the early larval feeding damage of "windowpanes" in the leaves. Neither the farmers whose crop incurred severe damage, nor those whose crop suffered mild crop damage due to FAW, could identify the shot holes or pinholes that are characteristic at the onset of FAW infestation. The misidentification of pest damage symptoms, and the failure to identify early FAW damage symptoms by farmers indicates the need for greater extension activity to educate the farmers on the biology and symptoms of FAW. It also affirms the important role that farmers should play in field monitoring and scouting for FAW to enable timely detection of pest infestations and prevent significant yield losses. This agrees with the recommendations of [14]. The most reported symptom of leaf-color change by farmers with moderate and mild damage to their maize is not a documented sign of FAW damage in maize and may therefore be associated with other factors not related to FAW. This suggests that farmers may fail to distinguish FAW damage when the crop suffers from an attack by FAW and other pests and diseases or other kinds of stress—such as nutrient deficiency, drought, or floods—which would confound efforts to combat relatively new challenges such as FAW. Moreover, the mild to moderate damage in some fields may be attributable to the ability of maize plants to recover from injury and compensate for growth in some cases. Damage recovery and growth compensation in maize that previously suffered FAW damage was observed in earlier studies [26]. Baudron et al. [27] established that perceived maize yield loses in SSA due to FAW may be overrated owing to the pest's feeding pattern resulting in tattered leaves that gives the appearance of devastation, whereas the maize plants may recover significantly. For effective prevention and control of FAW, there is a need to strengthen farmer education by improving extension services in response to FAW outbreaks. Tambo et al. [28] reported a 14% and 27% increase in maize yield and farmer income, respectively, following the participation of farmers in plant clinics, which included FAW damage identification and strategies for pest management in Zambia. This demonstrates the potential for farmer participatory integrated pest management (IPM) in the management of FAW and similar insect pests in SSA. The ability to identify FAW invasion and its symptoms could also be helpful in identifying sources of genetic resistance to the pest for breeding purposes, for example, in locally grown landraces that are resistant to FAW.

4.4. Maize Production Systems and Implications on FAW Impact and Management in the Chibombo and Chongwe Districts

Maize production systems and their characteristics such as farm sizes, land ownership, sources of seed and cropping systems have implications for the ability of farmers to control FAW. For instance, farmers with large farms will probably have greater access to casual labor and agricultural inputs that can be channeled towards FAW control. Small farms are more vulnerable because the crop can suffer complete decimation due to FAW infestation. The currently susceptible varieties grown by the farmers in the region exacerbate the impact of FAW damage [12]. Farmers in the Chibombo district (Nanswisa and Chititi camps) mainly practiced sole cropping, ensuring a widespread distribution of FAW. This also limited the diversity of FAW natural enemies in farmers' fields. The lack of alternative cropping systems exposes the farmers to severe food insecurity if the maize crop is completely destroyed.

4.5. Other Major Constraints to Maize Production in the Study Areas

The impact of FAW on farmers' incomes is compounded by the high cost of essential agricultural inputs. Poorly resourced farmers are compelled to prioritize between plant protection and plant nutrition inputs, resulting in compromised yields. The high cost of fertilizer and the inability of the farmers to apply optimal fertilizer levels means that the crop suffers from nutrient deficiencies, exacerbating the impact of FAW. The use of organic fertilizers could be explored as many farmers as possible in the survey areas reared goats, and this option could also enhance prospects for conservation agriculture. Conservation agriculture enhances species biodiversity and promotes conservation biocontrol, which harnesses the potential of prevailing natural enemies in pest management [29,30]. Drought stress compromises the ability of crops to withstand other biotic or abiotic stresses. Crops with sub-optimal nutrition and inadequate moisture are unhealthy and have a compromised ability to withstand pests. The prevalence of other insect pests and diseases (as mentioned by 31–38% of respondents) (Table 6), other than FAW, also contributes to the impact of FAW, either as secondary pests or acting in combination with FAW to reduce crop yields. Limited access to improved and high yielding varieties means that the farmers continue to cultivate landraces or low yield-potential cultivars, exposing them to food insecurity, even under mild or low FAW infestations that would have little impact on high yielding cultivars. It is essential that maize breeding programs consider climate, environmental changes, the dominant pests and diseases, and end-user preferences in their product profiles.

4.6. Farmer's Trait Preferences in a Maize Variety

There was a clear gender disparity in maize trait preferences and the factors perceived to affect production by male and female farmers (Table 8). Female farmers prioritized concern for agronomic management than crop protection-related factors. Male farmers, on the other hand, were more concerned with crop protection rather than agronomic factors. A gendered analysis on the participation of smallholder farmers in plant clinics affirmed that more male farmers visited and sought plant-protection related information from local plant clinics than female farmers [28]. This corroborates our findings on gendered prioritization of factors perceived to influence maize trait preferences by respondent farmers. Probably, female-owned maize fields could be more vulnerable to FAW and other production constraints due to limited economic means to control the FAW, a lack of particular attention to plant protection information, and the cultivation of low yielding and susceptible cultivars [31]. There is need to encourage interest in female farmers in Zambia to fully participate in plant protection-related interventions to ensure effective management of pests such as FAW. A positive aspect is that the preference displayed by female farmers for agronomic traits suggests that the prospects are good for farmer participatory breeding to develop FAW-resistant maize cultivars through a demand-led breeding approach. The advantages of demand-led breeding include the integration of farmers' perspectives, and a recognition of shifting market trends and drivers, enabling an accurate forecasting of cultivar adoption and therefore, ensuring value for investment in plant breeding [32]. Improved adoption rates of superior cultivars with FAW resistance would mitigate the impact of FAW, improve maize productivity and positively impact on household and national food security.

4.7. Farmers' FAW Coping Strategies and Future Directions in FAW Management

Knowledge of the use of resistant cultivars in the control of FAW was only reported by ~3% of the respondents (Section 3.4). This suggests that there has been insufficient information dissemination on the pest and the available control options to smallholder farmers. During the FGDs, some farmers indicated that they were aware that FAW resistant maize varieties were not yet available for use in the country. Therefore, these farmers resorted to the use of ash/sand applied to the leaf funnel in an attempt to control FAW, especially in the Chongwe district. In this area, farmers indicated that they did not have reliable access to chemical pesticides. Some desperate farmers formulated their own unorthodox pesticides by dissolving detergent paste in water. These farmers sometimes caused phytotoxic damage to their crops as a result. Although some of the farmers felt that the ash/sand or the detergent methods were effective in controlling FAW, further research is required to investigate the origin of these methods and whether they could be effective on a large scale. Several indigenous knowledge-based methods used by farmers in the management of FAW and other lepidopterans that closely resemble the FAW have been reported [4,33]. Farmers' management methods ranged from application of animal products such as cow dung and urine to plant parts. Other methods included the application of leaf-oil extracts to maize leaf whorls, which is under investigation as a potential FAW biocontrol strategy [1,2]. Some of the strategies mentioned by the farmers are only appropriate for small fields. These include application of sand/ash/lime in leaf whorls, detergent spraying, application of fertilizer granules to leaf whorls, scouting and manually crushing of FAW larvae (Section 3.4). The effectiveness of these strategies against FAW has not been validated and they may not be effective, leading to the spread of FAW and its negative impact on yield and food security [34].

The outbreak of FAW in 2016 compounded the effects of chronic production constraints in SSA, which had a severe impact on maize production and food security. Smallholder farmers lack effective FAW control strategies and have limited knowledge of the pest, which hinders FAW control efforts. Early identification of infestation and basic knowledge of aggravating maize production constraints by farmers will aid the development of participatory IPM strategies against FAW. In addition, the incorporation of farmer's indigenous knowledge in coping with FAW and their preferred traits in a maize variety will facilitate the deployment of IPM programs targeting FAW in maize growing communities. Further research is required to evaluate the efficacy of farmers' indigenous FAW coping strategies, gendered factors influencing the choice of FAW control methods and prospects for largescale conservation biocontrol. Information presented in this study will serve as a basis to breed for farmer-preferred maize varieties that integrate FAW resistance, for production in Zambia and related agro-ecologies in SSA.

Author Contributions: C.K.; Methodology, coordinated data collection, data analysis, writing of the manuscript draft, review and editing. H.S.: recourses, supervision, writing, conceptualization, review, and editing. M.D.L.: review and editing. A.S.: writing, review, and editing. I.M.: writing, review, and editing. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Alliance for a Green Revolution in Africa (AGRA) through a Ph. D scholarship at the African Centre for Crop Improvement (ACCI) at the University of KwaZulu-Natal, South Africa. The International Foundation for Science (IFS) funded the focused group discussions with farmers in Chongwe District through Grant No C/6147-1.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Ministry of Agriculture, District Agricultural Offices in the Chongwe and Chisamba districts of Zambia. Date of approval: 13th and 15th November 2017, respectively.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Acknowledgments: We sincerely thank the Zambia Agricultural Research Institute (ZARI) for hosting and supporting this work.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. FAO. Integrated Management of the Fall Armyworm on Maize: A Guide for Farmer Field Schools in Africa. Food and Agriculture Organization of United Nations. 2018. Available online: http://www.fao.org/publications/card/en/c/I8665EN/ (accessed on 23 January 2019).
2. Abrahams, P.; Beale, T.; Cock, M.; Corniani, N.; Day, R.; Godwin, J.; Gomez, J.; Moreno, P.G.; Murphy, S.T.; Opon-Mensah, B.; et al. Fall Armyworm Status, Impacts and Control Options in Africa: Preliminary Evidence Note. CABI, UKAid. 2018. Available online: https://www.invasive-species.org/Uploads/InvasiveSpecies/FAWinception-report.pdf (accessed on 30 November 2018).
3. Agboyi, L.K.; Mensah, S.A.; Clottey, V.A.; Beseh, R.G.; Rwomushana, I.; Day, R.; Kenis, M. Evidence of consumption rate decrease in fall armyworm, *Spodoptera frugiperda*, larvae parasitized by Coccygidium luteum. *Insects* **2019**, *10*, 410. [CrossRef] [PubMed]
4. Kansime, M.; Mugambi, I.; Rwomushana, I.; Nunda, W.; Lamontagne-Godwin, J.; Rware, H.; Phiri, N.A.; Chipabika, G.; Ndlovu, M.; Day, R. Farmer perception of fall armyworm (*Spodoptera frugiperda* J.E. Smith) and farm level management practices in Zambia. *Pest Manag. Sci.* **2019**, *7*, 2840–2850. [CrossRef] [PubMed]
5. Macauley, H.; Ramadjita, T. Cereal Crops: Rice, Maize, Millet, Sorghum, Wheat. Feeding Africa, 36. African Development Bank. 2015. Available online: Cereal_Crops_Rice__Maize__Millet__Sorghum__Wheat.pdf (accessed on 1 August 2021).
6. Diiro, G.M.; Seymour, G.; Kassie, M.; Muricho, G.; Murithi, B.W. Women's empowerment in agriculture and productivity: Evidence from rural maize farmer households in western Kenya. *PLoS ONE* **2018**, *13*, e0197995. [CrossRef] [PubMed]
7. Chapoto, A.; Chisanga, B.; Mulako, K. *Zambia Agricultural Status Report*; Indaba Agricultural Policy Research Institute (IAPRI): Lusaka Zambia, 2018; Available online: http://www.iapri.org.zm/research-reports/woring-papers (accessed on 23 November 2018).
8. OECD. *Crop Production Indicator*; OECD: Paris, France, 2018; Available online: https://dataoecd.org/agroutput/crop-production.htm (accessed on 30 November 2018).
9. Chapoto, A.; Subakanya, M. *Rural Agricultural Livelihoods Survey*; 2019 Survey Report; Indaba Agricultural Policy Research Institute (IAPRI): Lusaka, Zambia, 2019; Available online: http://www.iapri.org.zm (accessed on 14 December 2019).
10. Howard, J.A.; Mungoma, C. *Zambia's Stop-and-Go Revolution: The Impact of Policies and Organizations on the Development and Spread of Maize Technology*; International Development Working Paper; Michigan State University: East Lansing, MI, USA, 1996.
11. Niasey, S.; Agbodzavu, M.K.; Kimathi, E.; Mutune, B.; Abdel-Rahman, E.F.M.; Salifu, D. Bioecology of Fall Armyworm *Spodoptera frugiperda* (J.E. Smith), its Management and Potential Patterns of Spread in Africa. *PLoS ONE* **2021**, *16*, e0249042.
12. Kasoma, C.; Shimelis, H.; Laing, M.D. The fall armyworm invasion in Africa: Implications for maize production and breeding. *J. Crop Improv.* **2020**, *35*, 111–146. [CrossRef]
13. Wadell, R. Defeating the armyworm in Zambia. Sustainable agriculture. World Renew Zambia. 2017. Available online: https://worldrenew.net/blog/defeating-armyworm-zambia (accessed on 3 January 2018).

14. Prasanna, B.; Huesing, J.E.; Eddy, R.; Peschke, V. *Fall Armyworm in Africa: A Guide for Integrated Pest Management*; CIMMYT; USAID: Mexico City, Mexico, 2018. Available online: https://respository.cimmyt.org/xmlui/handle/10883/19204 (accessed on 14 December 2018).
15. Mrema, E.; Shimelis, H.; Laing, M.; Bucheyeki, T. Farmers' perceptions of sorghum production and *Striga* control practices in semi-arid areas of Tanzania. *Int. J. Pest Manag.* **2017**, *63*, 146–156. [CrossRef]
16. Odendo, M.; De Groote, H.; Odongo, O. Assessment of farmers' preferences and constraints to maize production in moist mid-altitude zone of western Kenya. In Proceedings of the 5th International Conference of the African Crop Science Society, Lagos, Nigeria, 21–26 November 2001.
17. Mukanga, M.; Derera, J.; Tongoona, P.; Laing, M. Farmers' perceptions and management of maize ear rots and their implications for breeding for resistance. *Afr. J. Agric. Res.* **2011**, *6*, 4544–4554.
18. Daudi, H.; Shimelis, H.; Laing, M.; Okori, P.; Mponda, O. Groundnut production constraints, farming systems and farmers-preferred traits in Tanzania. *J. Crop Improv.* **2018**, *36*, 812–828. [CrossRef]
19. Chambers, R. The origins and practice of participatory rural appraisal. *World Dev.* **1994**, *22*, 953–969. [CrossRef]
20. Cornwall, A. Whose voices? Whose choices? Reflections on gender and participatory development. *World Dev.* **2003**, *31*, 1325–1342. [CrossRef]
21. *IBM Corp IBM SPSS Statistics for Windows*; Version 24.0; IBM Corp: Armonk, NY, USA, 2016.
22. CGIAR. Gender in Maize. Consultative Group on Agricultural Research. 2016. Available online: https://maize.org/gender-inmaize/ (accessed on 3 January 2017).
23. Hruska, A.J.; Gould, F. Fall armyworm (Lepidoptera: Noctuidae) and *Diatraea lineolate* (Lepidoptera: Pyralidae): Impact of larval population level and temporal occurrence on maize yield in Nicaragua. *J. Econ. Entomol.* **1997**, *90*, 611–622. [CrossRef]
24. Mihn, J. *Efficient Mass Rearing and Infestation Techniques to Screen for Resistance to Spodoptera Frugiperda*; CIMMYT: Mexico City, Mexico, 1983.
25. Rosenzweig, C.; Iglesias, A.; Yang, X.; Epstein, P.R.; Chivan, E. Climate change and extreme weather events: Implications for food production, plant diseases and pests. *Glob. Chang. Hum. Health* **2001**, *2*, 90–104. [CrossRef]
26. Wiseman, B.; Davis, F.M. Plant resistance to the fall armyworm. *Fla. Entomol.* **1979**, *62*, 123–130. [CrossRef]
27. Baudron, F.; Zaman-Allah, M.A.; Chaipa, I.; Chari, N.; Chinwada, P. Understanding the factors influencing fall armyworm (*Spodoptera frugiperda* J.E. Smith) damage in African smallholder maize fields and quantifying its impact on yield. A case study in eastern Zimbabwe. *Crop. Prot.* **2019**, *120*, 41–150. [CrossRef]
28. Tambo, J.A.; Matimelo, M.; Ndhlovu, M.; Mbugua, F.; Phiri, N. Gender-differentiated impacts of plant clinics on maize productivity and food security: Evidence from Zambia. *World Dev.* **2021**, *145*, 105519. [CrossRef]
29. Begg, G.S.; Cook, S.M.; Dye, R.; Ferrante, M.; Franck, P.; Lavigne, C.; Lovei, G.L.; Mansion-Vaquie, A.; Pell, J.K.; Petit, S.; et al. A functional overview of conservation biological control. *Crop Prot.* **2017**, *97*, 145–158. [CrossRef]
30. Durocher-Granger, L.; Mfune, L.; Musesha, M.; Lowry, A.; Reynolds, K.; Buddle, A.; Cafa Offord, L.; Chipabika, G.; Dicke, M.; Kenis, M. Factors influencing the occurrence of fall armyworm parasitoids in Zambia. *J. Pest Sci.* **2020**, *94*, 1133–1146. [CrossRef]
31. Ochago, R. Gender and pest management: Constraints to integrated pest management uptake among smallholder coffee farmers in Uganda. *Cogent Food Agric.* **2018**, *4*, 1540093. [CrossRef]
32. Shimelis, H. New variety design and product profiling. In *The Business of Plant Breeding: Market-led Approaches to New Variety Design in Africa*; Persley, G.J., Anthony, V.M., Eds.; CABI International: Wallington, UK, 2017; pp. 85–114.
33. Yigezu, G.; Wakgari, M. Local and indigenous knowledge of farmers management practice against fall armyworm (*Spodoptera frugiperda*) (J.E Smith) Lepidoptera: Noctuidae: A review. *J. Entomol. Zool. Stud.* **2020**, *8*, 765–770.
34. Harrison, R.D.; Thierfelder, C.; Baudron, F.; Chinwada, P.; Midega, C.; Schaffner, U.; van den Berg, J. Agro-ecological options for fall armyworm (*Spodoptera frugiperda* J.E. Smith) management: Providing low-cost, smallholder friendly solutions to an invasive pest. *J. Environ. Manag.* **2019**, *24*, 318–330.