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Eswatini Maize Farmers' Perceptions, Knowledge, and Mycotoxin Management: Implications for Food Safety and Agricultural Development

Ngwenya Siboniso Frank, Diana Marie Earnshaw, Yoseph Assefa*

Department of Crop Production, Faculty of Agriculture, University of Eswatini, Luyengo Campus, Luyengo M201, Kingdom of Eswatini.

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Corresponding author: Yoseph Assefa, Department of Crop Production, Faculty of Agriculture, University of Eswatini, Luyengo Campus, Luyengo M201, Kingdom of Eswatini.

Abstract

Maize (*Zea mays* L.) is the primary staple crop in Eswatini, crucial for food security and livelihoods. However, suboptimal farming and post-harvest practices in the subtropical climate create conditions conducive to mycotoxin contamination, posing risks to human and animal health. This study investigated the perceptions, knowledge, and mycotoxin management practices of 156 maize farmers across Eswatini's agro-ecological zones using a structured questionnaire. Results revealed that while most farmers (94%) recognized moldy maize as unhealthy, a significant proportion (90.3%) still fed it to animals, and a small percentage (5.3%) consumed it. Post-harvest handling often involved leaving maize in the field, and drying methods varied, with maize cribs being common but field drying also prevalent. Shelling was largely mechanized (84.8%), and selling was the primary post-shelling action (92.7%). Storage durations varied, with longer periods in the Highveld. These findings highlight critical gaps in understanding the systemic risks of mycotoxins and the need for improved post-harvest management and targeted education. Tailored educational programs, strengthened extension services, infrastructure improvements, promotion of safe storage, public awareness campaigns, and further research and monitoring to mitigate mycotoxin contamination are essential to enhance food safety and agricultural development in Eswatini.

Keywords

Contamination; Eswatini; Farmers' knowledge; Maize; Mycotoxin

1. Introduction

Maize (*Zea mays* L.) is the primary crop in the Kingdom of Eswatini, covering 80% of cultivated land and mainly grown for subsistence [1]. In the Kingdom of Eswatini, maize is a staple food forming the cornerstone of household food security and contributing significantly to the livelihoods of its over one million inhabitants [2]. However, despite being the dominant crop in Eswatini's agricultural sector that plays a vital role in sustaining the livelihoods of its more than one million people, the nation persistently struggles to achieve self-sufficiency in maize, with suboptimal farming practices contributing significantly to this shortfall [3]. These include, but are not limited to, reliance on traditional farming methods [4], limited adoption of improved inputs [5], and inadequate strategies for managing the increasing pressures of pests and diseases [6]. Moreover, Eswatini generally experiences a sub-tropical climate characterized by warm, wet summers and mild, dry winters [7]. The high temperatures and humidity levels during the growing and harvesting seasons create ideal conditions for the growth of fungi such as *Aspergillus flavus* and *Fusarium* species [8]. These pathogens are known to produce mycotoxins, such as aflatoxins, fumonisins, and zearalenone in maize both in the field and during storage [9].

Mycotoxins are secondary metabolites produced by filamentous fungi, particularly molds belonging to the

Aspergillus, Fusarium, Penicillium, Claviceps, and Alternaria genera [10]. Mycotoxins, such as aflatoxins, fumonisins, and zearalenone, are potent toxins that can accumulate in maize grains in the field and during post-harvest handling and storage [11]. Exposure to mycotoxins occurs primarily through the food chain by ingestion of contaminated food [12]. Chronic exposure to mycotoxins has been linked to a range of adverse health effects, including immunosuppression, liver damage, kidney problems, neurological disorders, and increased risk of certain cancers [13]. Children are particularly vulnerable to the harmful effects of mycotoxins, potentially leading to growth impairment and developmental delays [13].

Despite the potential for significant health and economic impacts, the extent to which maize farmers in Eswatini are aware of mycotoxins, understand the associated risks, and implement appropriate management practices remains largely unexplored [14]. Their perceptions of the mycotoxin risk, their knowledge about the causes and consequences of contamination, and the management methods they currently employ are crucial factors influencing the prevalence and levels of mycotoxins in the Eswatini maize supply chain.

This paper aims to explore the current understanding of Eswatini maize farmers' perceptions, knowledge, and practices related to mycotoxin management. By understanding their sources of information and the barriers they face in implementing and identifying potential knowledge gaps, this review seeks to highlight the challenges and opportunities for developing targeted interventions to minimize mycotoxin contamination and enhance food safety and agricultural sustainability in Eswatini. The findings of this research will contribute valuable insights for developing targeted educational programs, improving agricultural extension services, and formulating effective strategies to minimize mycotoxin contamination in the maize supply chain in Eswatini, ultimately safeguarding public health and supporting sustainable agricultural practices.

2. Materials and Methods

2.1 Study Area

The study was conducted in the main maize production areas in all the agro-ecological zones of Eswatini (Figure 1). The country is divided into four major agro-climatic zones which are namely the highveld, middleveld, Lowveld and the Plateau [15]. Dlamini et al. [3] explained that the middleveld is further divided into two zones which is the higher middleveld (wet middleveld) and lower middleveld (dry middleveld) while the lowveld consists of the eastern and western lowveld. Most of the crop production is done in the highveld which is known to receive more rainfall than the other zones, followed by the wet middleveld, Plateau, dry middleveld and lowveld. Land ownership is divided into two divisions which are the Swazi National Land (SNL) and the Title Deed (TD) where the former is mostly associated with subsistence farmers and semi-commercial farmers while the latter is mostly associated with commercial farmers.

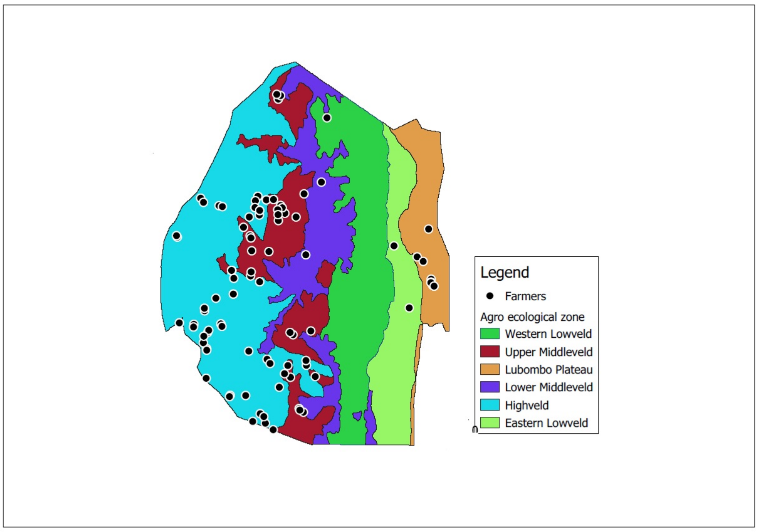

Figure 1. Map of Eswatini showing Agro-ecological zones surveyed.

2.2 Farmer Survey

The survey was conducted by means of a structured questionnaire during March to May 2024 and was administered to active contracted maize farmers from the National Maize Corporation's (NMC) database in 2023. A stratified random design was used to decide on the number of farmers to be interviewed in each agro-ecological zone's geographical regions. A total of 156 farmers were selected for the interviews from 256 active contracted maize farmers in the NMC database using Yamane's [16] simplified formula to calculate sample size. Selected farmers were then interviewed on their farms, in villages or on their way to the local markets. Their responses to questions on weed and insect pest management, drying methods, shelling, maize storage, and understanding and perceptions of mycotoxins contamination of maize were recorded.

2.3 Data Analysis

Data were summarized in Excel and expressed as percentages that were calculated based on the total number of farmers who responded to a particular question. Farmers who did not respond to a particular question, or if it was not applicable, were excluded from the calculation of percentage values for that question. When a farmer selected more than one answer to a question, percentages were calculated using all answers given.

3. Results

3.1 Household and Farm Characteristics

The Highveld region accounted for the largest number of interviewed maize producers (60), in contrast to the Western Lowveld's 10 farmers (Table 1). Male farmers constituted a significant majority (89.8%) of the surveyed population. Across the agro-climatic regions, primary education was the highest level reached for about half of the respondents (average 51.25%), while a smaller proportion had no education (average 12.75%) (Table 1). Farmer ages varied considerably, from 24 to 77 years, with the Lubombo plateau exhibiting the highest average age (57.2 years) compared to other zones. Household sizes ranged from three to ten people, with an average of at least 3.97 family members involved in farming. Land ownership varied from 3 to 50 hectares, with farmers dedicating nearly half (average 47.67%) of their land to maize production, representing almost two-thirds of their total land allocation (Table 1).

Table 1. Household and Farm Characteristics of Farmers Interviewed

	Western Lowveld	Upper Middleveld	Lubombo Plateau	Lower Middleveld	Highveld	Eastern Lowveld	Average
No. of Farmers	10 (6.4%)	44 (28.2%)	17 (10.9%)	14 (10%)	60 (38.5%)	11 (7.1%)	26 (16,7%)
Gender of household (%)							
Male	100.00	90.90	82.40	85.70	80.00	100.00	89.80
Female	0.00	9.10	17.60	14.30	20.00	0.00	10.20
Schooling Level (%)							
No Education	0.00	20.50	0.00	14.30	41.70	0.00	12.75
Informal	0.00	11.40	11.80	7.10	21.70	0.00	8.70
Primary	50.00	50.00	52.90	42.90	11.70	100.00	51.25
Secondary	50.00	0.00	23.50	21.40	11.70	0.00	17.80
Tertiary	0.00	18.10	11.80	14.30	13.20	0.00	9.50
Household head's age							
Average	45.90	48.30	57.20	54.80	41.10	50.80	49.68
Range	24-63	29-68	43-70	32-67	33-77	29-72	24 -77

Table 1 Continued

Family Size							
Average	4.90	6.10	7.40	4.20	5.30	6.90	5.80
Range	3-6	4-8	3-10	3-8	3-8	5-10	3-10
Members involved in Farming							
Average	3.20	3.50	5.10	3.10	4.20	4.70	3.97
Range	3-5	3-6	3-9	2-5	2-7	2-8	2-9
Land Size in hectares							
Average	6.90	5.30	7.50	5.10	18.00	14.80	9.60
Range	3-15	3-30	3-20	4-8	3-50	3-22	3-50
Percentage of land allocated to Maize							
Average	45.00	80.00	63.00	59.00	85.00	33.00	60.83
Range	40-60	60-90	45-70	55-69	70-90	31-55	31-90

3.2 Common Pests and Pest Management Practices

Fall armyworm (FAW) was the most frequently reported insect pest, affecting an average of 52.3% of farmers' fields (Figure 2). Notably, approximately 34% of the farmers interviewed experienced infestations of both fall armyworm and cutworms (CW). The overwhelming majority of farmers (over 93%) relied on chemical pest control in the management of insect pests, while a small percentage (6.4%) employed cultural methods such as field clearing and crop rotation. Maize streak virus (MSV) was the most prevalent disease, affecting 58.4% of interviewed farmers. For disease management, the primary approach (79.6%) was the use of resistant maize varieties (genetic control) (Figure 2).

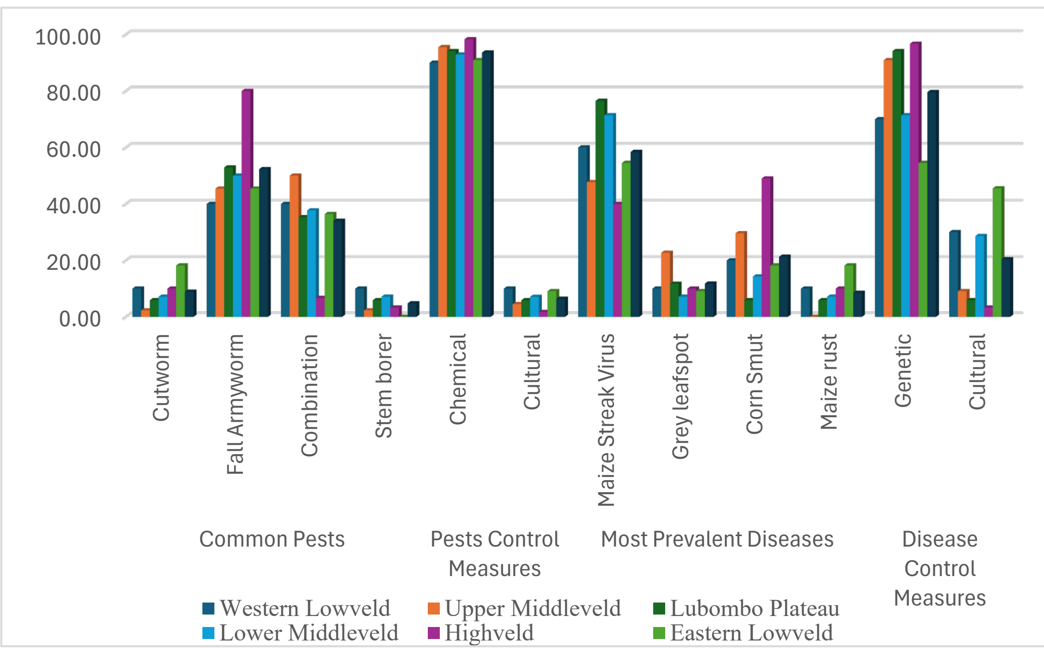

Figure 2. Common Pests, Diseases, and Their Control.

3.3 Maize Harvesting Practices

The majority of surveyed farmers (78.9%) employed a stocking method for maize harvesting, with the highest adoption rate observed in the upper middleveld (88.7%) (Table 2). The remaining respondents utilized husking or machinery for harvesting (about 10% each). A significant proportion of farmers (69.2%) reported leaving harvested maize in the field for 1 to 2 days, primarily due to transportation limitations, insufficient labor, or a combination of both. Notably, about 15.9% of farmers in the upper middleveld took up to five days to complete the collection of cobs from their fields.

Table 2. Maize Harvesting Practices of the interviewed farmers

	Western Lowveld	Upper Mid-dleveld	Lubombo Plateau	Lower Mid-dleveld	Highveld	Eastern Lowveld	Average
Harvesting Method							
Stocking	80.00	88.70	88.20	78.60	83.30	54.50	78.90
Dehusking	10.00	6.80	11.80	21.40	5.00	9.10	10.70
Machinery	10.00	4.50	0.00	0.00	11.70	36.40	10.40
Keeping maize infield after harvesting							
0 days	20.00	11.40	11.80	21.40	16.70	36.40	19.60
1 - 2 days	70.00	72.70	76.40	71.50	70.00	54.50	69.20
3 - 5 days	10.00	15.90	11.80	7.10	13.30	9.10	11.20

3.4 Drying and sorting practices employed by maize farmers

Table 3 illustrates the diverse drying and sorting practices employed by maize farmers across different agro-climatic regions. A significant majority of farmers (86.4%) reported separating rotten or non-rotten maize before drying, with the upper middleveld showing the highest rate (93.2%). In contrast, sorting by size or separating soily/clean maize was less common, averaging 3.7% and 4.5% respectively. Regarding drying structures, maize cribs were the most widely used method (average 78.9%), particularly in the western lowveld (80.0%), upper middleveld (93.2%), Lubombo plateau (82.3%), lower middleveld (85.7%), and highveld (86.6%). Drying maize on the field was practiced by an average of 12.8% of farmers, with the eastern lowveld having the highest proportion (36.4%). Other less frequent drying methods included using the ground on mats (5.8%) and rooftops (2.5%).

Table 3. Drying and sorting practices employed by the interviewed maize farmers

	Western Lowveld	Upper Mid-dleveld	Lubombo Plateau	Lower Mid-dleveld	Highveld	Eastern Lowveld	Average	Western Lowveld
Sorting of maize Before Drying								
No sorting	10.00	0.00	5.90	7.10	0.00	9.10	5.40	No sorting
Sort size	10.00	2.30	0.00	0.00	10.00	0.00	3.70	Sort size
Type of Drying Structure								
Roof tops	0.00	0.00	5.90	0.00	0.00	9.10	2.50	Roof tops
Mats	10.00	2.30	11.80	0.00	1.70	9.10	5.80	Mats
Maize Crib	80.00	93.20	82.30	85.70	86.60	45.40	78.9	Maize Crib
Field Dry-ing	10.00	4.50	0.00	14.30	11.70	36.40	12.80	Field Drying

3.5 Maize Shelling and Storage

Maize shelling was predominantly mechanized across the surveyed areas, as evidenced by the average of 84.8% of farmers using shelling machinery (Table 4). This practice was most widespread in the Highveld (95.0%). Conversely, traditional shelling and the use of hand shellers were less frequent, accounting for averages of 6.0% and 9.2% respectively. The immediate post-shelling action for the vast majority of farmers (average 92.7%) was selling their maize, a trend particularly strong in the upper middleveld (97.7%). Storing maize directly after shelling was a less common practice, reported by an average of only 7.3% of the farmers.

Table 4. The effects of additives during thermal food processing on the reduction of OTA

	Western Lowveld	Upper Mid-dleveld	Lubombo Plateau	Lower Mid-dleveld	Highveld	Eastern Lowveld	Average
Method of Shelling							
Traditional	10.00	2.30	5.90	7.10	1.70	9.10	6.00
Hand sheller	10.00	4.50	11.80	7.10	3.30	18.20	9.20
Shelling machinery	80.00	93.20	82.30	85.70	95.00	72.70	84.80
Action after Shelling							
Sell Maize	90.00	97.70	88.20	92.90	96.70	90.90	92.70
Store	10.00	2.30	11.80	7.10	3.30	9.10	7.30

3.6 Farmers' Knowledge of Mycotoxins and Contamination of Maize

The most common maize storage duration reported by respondents was three to five months (average 57.7%), although a significant 71.7% of Highveld farmers stored their maize for up to twelve months (Table 5). While most farmers (average 68.9%) rarely observed mould in their stored grain, a concerning average of 90.3% still believed in feeding potentially mycotoxin-contaminated maize to animals. Alarmingly, despite an average of 94.0% of farmers recognizing mouldy maize as unhealthy, about 5.3% still consumed it, with 10% of farmers in the Lubombo Western Lowveld admitting to this practice (Table 5).

Table 5. Maize storage practices and the interviewed farmers' understanding of mycotoxins

	Western Lowveld	Upper Mid-dleveld	Lubombo Plateau	Lower Mid-dleveld	Highveld	Eastern Lowveld	Average
Duration of keeping maize in storage							
Less than a month	20.00	0.00	5.90	7.15	0.00	9.10	7.00
1 - 2 months	30.00	6.80	5.90	14.30	3.30	18.20	13.10
3 - 5 Months	50.00	68.20	58.80	71.40	25.00	72.70	57.70
Mould development in storage							
No	10.00	90.90	11.80	7.10	3.30	0.00	20.50
Rare	80.00	6.80	76.40	78.60	90.00	81.80	68.90
Sometimes	10.00	2.30	5.90	14.30	6.70	18.20	9.60
Handling mould-affected maize							
Dispose it	0.00	9.10	0.00	7.15	10.00	0.00	4.40
Feed it to Animals	90.00	90.90	94.10	85.70	90.00	90.90	90.30
Consume it	10.00	0.00	5.90	7.15	0.00	9.10	5.30
Perception of mould causing health disorders							
Yes	90.00	97.70	94.10	92.90	98.30	90.90	94.00
No	10.00	2.30	5.90	7.10	1.70	9.10	6.00

4. Discussion

This study provides valuable insights into the perceptions, knowledge, and mycotoxin management practices of maize farmers in Eswatini. Comparing these findings with similar studies conducted in other sub-Saharan African countries reveals both consistencies and areas where Eswatini presents a unique context.

The demographic profile of the surveyed farmers indicates a predominantly male farming population with a significant proportion having attained only primary education. This is agreement with the general perception in some regions of sub-Saharan Africa where agriculture is often seen as male-dominated [17]. However, the reality across sub-Saharan Africa is diverse, with women playing crucial roles in smallholder farming, particularly in food crop production [18]. Educational level can significantly affect adoption of technologies [19]. The study by Dlamini et al. [20] reported that a significant proportion (64%) of their respondents had attained high school education. Compared to some other regions in sub-Saharan Africa where literacy and education levels in rural farming communities might be lower, this could indicate a relatively higher level of formal education among Eswatini maize farmers in that particular study. This suggests that agricultural extension and educational interventions need to be tailored to this demographic, considering literacy levels and traditional knowledge systems. The reliance on family labor and the allocation of a substantial portion of land to maize underscore the crop's importance for livelihoods, highlighting the potential impact of mycotoxin contamination on household food security and economic well-being.

The reliance on family labor and the allocation of a substantial portion of land to maize underscore the crop's importance for livelihoods, highlighting the potential impact of mycotoxin contamination on household food security and economic well-being. This aligns with the general pattern of maize production in sub-Saharan Africa, where smallholder farmers with limited landholdings are the dominant producers [20, 21] and agriculture often supports extended families [18]. The reliance on traditional post-harvest handling methods in Eswatini, such as stocking maize in the field, is a practice that increases the risk of fungal growth and mycotoxin contamination, consistent with findings in Maize Farmers in Trans Nzoia County of Kenya [11]. The dominance of mechanized shelling (84.8%) in Eswatini is a relatively advanced practice compared to some other sub-Saharan African countries where manual shelling is still prevalent. Mechanization can potentially reduce damage to grains, which can be a point of entry for fungi. However, the primary post-shelling action being selling (92.7%) suggests that a large proportion of the harvest enters the market quickly, potentially bypassing on-farm storage risks but also highlighting the need for mycotoxin monitoring along the value chain.

This finding underscores the importance of tailored interventions based on the specific storage practices and climatic conditions of each region within Eswatini. The variation in storage durations, with longer storage in the Highveld (up to 12 months for 71.7% of farmers), indicates differing post-harvest management needs across agro-ecological zones. Longer storage periods inherently increase the risk of mycotoxin development if storage conditions are not optimal [11]. The use of maize cribs for drying in Eswatini is a relatively good practice for aeration, also common in some parts of Africa [22]. However, the significant proportion of farmers drying maize on the field in Eswatini, particularly in the lowveld, mirrors risky practices in other regions that expose maize to moisture and fungal proliferation [23].

The study clearly highlights significant knowledge gaps regarding the systemic risks of mycotoxins. While farmers recognize mould as unhealthy, their practices of feeding it to animals and, to a lesser extent, consuming it demonstrate a lack of understanding of the invisible threat of mycotoxins and their potential transfer through the food chain. This is consistent with findings in other African studies where awareness of the specific dangers of mycotoxins beyond visible mould is limited [24, 14]. The implications of these findings for food safety and agricultural development in Eswatini are significant. The potential for chronic exposure to mycotoxins through contaminated maize poses a serious threat to public health, potentially contributing to immunosuppression, liver damage, and other health issues, as highlighted by Awuchi et al. [25]. Furthermore, mycotoxin contamination can lead to economic losses through reduced marketability of maize and potential trade barriers.

5. Conclusion

This study reveals that while Eswatini maize farmers exhibit some progressive practices like mechanized shelling, significant challenges remain in mycotoxin management due to reliance on traditional post-harvest methods, varying storage durations across agro-ecological zones, risky drying practices, and critical knowledge gaps regarding the systemic dangers of mycotoxins. These findings underscore the urgent need for targeted interventions, including education on mycotoxin risks and safe post-harvest handling and storage practices, tailored to the specific socio-demographic characteristics and agro-ecological conditions of Eswatini to safeguard public health and economic well-being.

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