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# Effects of the Use of Good Agricultural Practices on Aflatoxin Levels in Maize Grown in Nandi County, Kenya

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**Abstract:** Aflatoxin contaminated maize is of public health concern in Kenya. Training farmers on good agricultural practice (GAP) has been touted as a mitigative measure. Little is known of the effect of such training on aflatoxin levels in maize grown in Kenya. This study evaluated what effect training farmers on GAP has on aflatoxin levels in maize grown in Kaptumo, Kilibwoni, and Kipkaren divisions in Nandi County, Kenya. Ninety farmers were recruited into farmer field schools and a questionnaire on GAP administered to each farmer. Maize samples were collected from the farmers and analyzed for aflatoxins using competitive enzyme-linked immunosorbent assay (c-ELISA). All farmers weeded their farms before planting, prepared the land, correctly spaced the seedlings, sorted the maize after shelling, cleaned stores before use and knew that aflatoxins were harmful to humans and animals. Eighty-one farmers did early planting, 88/90 did stooking after harvesting, 89/90 applied fertilizer, 89/90 cleared bushes around the stores, 87/90 used wooden pallets to store maize, 89/90 dried maize after harvesting, 83/90 did crop rotation, and 89/90 used clean transport. Moreover, 62/90 had a relative who had died from liver cancer, 13/90 had fed damaged/rotten seeds to animals, and 45/90 had stored harvested seeds on the ground. The mean aflatoxin levels in season 1 were significantly different from season 2 ( $1.918 \pm 1.065$ ;  $1.301 \pm 1.501$ ). Our findings suggest that some aspects of the training on GAP were better received than others. Training farmers on GAP results in a decrease in aflatoxin levels in maize grown in Nandi County. Farmers in other maize growing areas of Kenya may benefit from similar training on GAP.

**Keywords:** good agricultural practice; aflatoxin; Nandi County; mycotoxins; Kenya; maize

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## 1. Introduction

Aflatoxins are a group of mycotoxins that are produced by soil-borne fungi (*Aspergillus species*) that are ubiquitous in nature [1]. The major types are AFB<sub>1</sub>, AFB<sub>2</sub>, AFG<sub>1</sub>, and AFG<sub>2</sub> [1]. Most species of *Aspergillus* produce B-type aflatoxins although species related to *A. parasiticus* and *A. nomius* have the capacity to produce G-type aflatoxins [1]. The fungus may be recognized by a grey-green or yellow-green mold growing on corn kernels in the field or in storage [2]. Aflatoxins are carcinogenic,

mutagenic, and immunosuppressive in both humans and animals [1]. At high levels of exposure, they can cause acute toxicity and potentially death in mammals, birds, and fish [1].

Aflatoxins have received quite a bit of attention in Kenya over the last three decades [3–9], the most recent of which has been the case of aflatoxin contaminated peanut butter [10–12]. Associations between the nutritional status of children and dietary exposure to aflatoxins have been reported in studies conducted in Nairobi and Kisumu [13,14]. Children under 30 months of age in one county (Makueni) have been reported to have 1.4 times higher levels of aflatoxin M<sub>1</sub> in urine than those of the same age in another county (Nandi) [7]. It has also been reported that aflatoxin and fumonisin levels in animal feed, milk, and sorghum in selected areas of Kenya have exceeded critical limits set by the Kenya Bureau of Standards and WHO/FAO [5,7,15].

Several toxigenic strains of *Aspergillus* species have been isolated from maize kernels from two maize growing areas of the country (Nandi and Makueni) [3]. Moreover, a study on Kenyan dairy farmers' perception to molds and mycotoxins reported that farmers had a low understanding of the dangers of mycotoxins in food, and in some instances, farmers carried out practices that increased the risk of exposure to mycotoxins [16]. At the same time, groups that had knowledge of aflatoxin were not always responsible for risk mitigation [16].

Death resulting from acute aflatoxicosis has also been reported in the country [17–19]. In 1981, there were 20 cases of acute aflatoxicosis in parts of the former Eastern province [17]. This was occasioned by a severe drought followed by heavy rains that fell during the harvesting period [17]. Between January and June 2004, 125 of 317 people who presented to various hospitals in the former Makueni and Kitui districts with symptoms of acute aflatoxicosis succumbed to aflatoxin poisoning [18]. Investigations revealed that the concentration of aflatoxin B<sub>1</sub> in some maize samples from the area was a staggering 220 times above the critical limit for food [18]. Following this outbreak, a 2004 study set out to determine the extent of regional contamination and status of maize in commercial markets [19]. This study reported that 50% of maize products sampled had aflatoxin levels greater than the Kenyan regulatory limit (20 ppb at the time). The same study also reported that 35% of maize samples tested had levels > 100 ppb and 7% had levels > 1000 ppb [19].

Barely a year after the 2004 outbreak, 32 out of 75 people with symptoms of acute aflatoxicosis in the same area (Makueni and Kitui) died following aflatoxin exposure [20]. Investigations revealed that locally produced maize from subsistence farming was the likely source of contamination that resulted in the two outbreaks [20].

In 2010, two and a half million bags (each 90 kg in weight) of aflatoxin contaminated maize was seized by authorities in Kenya [1]. A year later, Proctor and Allan East Africa (a major cereals manufacturer in the region) recalled 25 tonnes of relief food (Unimix; a high-protein maize meal) after it was discovered to be contaminated with aflatoxins [21]. The contaminated batch was to be sent to areas in the country adversely hit by drought [21].

While all these published works provide valuable and resourceful information and recommendations, there has been very little research in the form of measures aimed at mitigating this public health problem. Sound agronomic and post-harvest practices including training farmers on good agricultural practice may reduce aflatoxin contamination in maize. However, little is known of the effect of such training on aflatoxin levels in maize grown in Kenya. The aim of the present study was to determine what effect training farmers in Nandi County on good agricultural practice may have on aflatoxin levels in maize grown in the region.

## 2. Materials and Methods

### 2.1. Study Area

Nandi County is part of the former Rift Valley Province in Kenya and covers an area of about 2900 Km<sup>2</sup> [3,22]. It lies between longitude 35°08'60.00" E and latitude 0°10'0.00" N [23] and is elevated between 1000 and 2000 m above sea level [3]. The area receives about 1000–1500 mm of rainfall on average with a mean temperature of about 20 °C [3]. Kaptumo, Kilibwoni, and Kipkaren divisions in

the county (Figure 1) were selected as study areas as these have been reported to be the areas where maize cultivation is actively practiced [3].

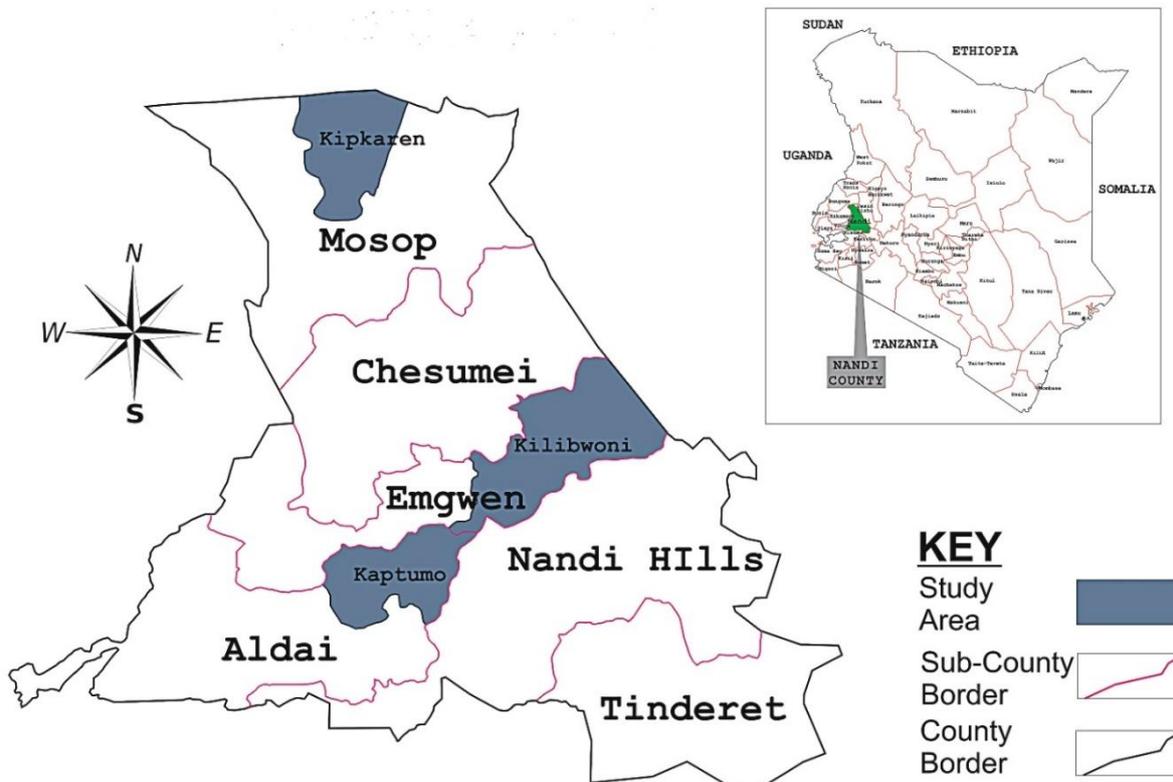


Figure 1. Map of Nandi County showing the study areas.

### 2.2. Study Design

This was a cross-sectional study carried out in two maize planting seasons in Nandi County (January–November 2016; season 1, and January–November 2017; season 2). The study involved a cross-sectional survey of farmers’ knowledge on good agricultural practice in selected divisions of Nandi County. Farmers who were willing to participate in the survey and were above 18 years of age were considered eligible for the study. These farmers were further divided into 6 farmer field schools. The farmer field schools included Mwangaza and Keteba in the Kaptumo division, Sobetab Gaa and Toret Gaa in the Kipkaren division, and Toletany and Kisob Katanin in the Kilibwoni division. A questionnaire was then administered to each farmer and for each farmer interviewed, a maize sample was also collected for aflatoxin analysis at the Mycotoxin Research Centre at the Department of Public Health, Pharmacology and Toxicology, University of Nairobi.

### 2.3. Data Collection

A 33-item questionnaire was designed for use in this study. Each question was read to each farmer to ensure that they understood what was being asked. The questionnaire consisted of the following sections.

#### 2.3.1. Section 1: Socio-Demographic Information

Seven questions were contained in this section and inquired about general information including the gender of the farmers, his/her division, the name of the farmer field school, and the number of years the farmer had practiced farming. Others included the acreage of the farms, whether the farmers had other sources of income, and the nature of the farming practiced.

### 2.3.2. Section 2: Questions Related to Good Agricultural Practice

This section contained 26 questions which included inquiries on top dressing, stooking, whether the stores were raised above the ground and had wooden pallets, and the level of awareness farmers had with regard to aflatoxins. Other questions touched on plant spacing, use of fertilizer and manure, quantities of fertilizer used per acre, how dry the maize was at harvesting time, and how the maize was harvested. There were also questions on whether harvested maize was put on mats/racks or on the ground, whether the maize eventually went to the store or to the ground of the house and whether the farmers checked on the maize in the store to see if it was still in good condition. Moreover, questions on early planting, land preparation, weeding and cleaning of the stores were asked. Other questions included the time the maize was dried, sorting practices and when this was done, application of insecticides, crop rotation, and whether they were feeding maize seeds that were damaged to animals or not. Finally, the means of transport used by the farmers was also asked.

### 2.4. Sample Collection

About 2 kilograms of shelled maize kernels were collected from each interviewed farmer by use of a closed spear driven through the upper parts and sides of bags containing maize kernels. This was then transferred to sterile bags which were then sealed, and each bag was assigned unique identification codes. The sealed bags were stored away from heat and sunlight and transported to the Department of Public Health, Pharmacology and Toxicology of the University of Nairobi awaiting analysis.

### 2.5. Preparation of Maize Samples and Analysis of the Levels of Aflatoxin

The samples were ground by use of a grinder (Grindomix® G200; Retsch GmbH 42781, Haan, Germany) to a fine powder at the mycotoxin research center of the University of Nairobi. Two grams of the ground samples were accurately weighed by use of a weighing balance (Shimadzu Corp TX 42021) and transferred to 50mL falcon tubes (Thermo Fisher Scientific, Waltham, MA, USA). Aflatoxin extraction was performed by adding 70% methanol to the 2 g of maize powder and the falcon tubes shaken for 10 min. One hundred microliters of the supernatant was collected and transferred to a 2 mL Eppendorf tube and 600 µL was added to the supernatant and the mixture vortexed by use of a Wisemix® VM10-Korea vortex machine.

### 2.6. Determination of Aflatoxin Levels in the Prepared Samples

The total aflatoxin levels in the prepared samples and standard dilutions were tested using a competitive enzyme-linked immunosorbent assay (ELISA) kit (Ridascreen® Aflatoxin Total, R4701, R-Biopharm AG, Darmstadt, Germany) as per manufacturer's instructions [24].

Briefly, 50 µL of the prepared sample extracts and standard dilutions was pipetted in duplicate into 96-well microtiter plates. Fifty microliters of the conjugate was then added to each well followed by 50 µL of the antibody. The contents of the plate were then mixed gently by gently shaking the plate manually. The resultant mixture was then incubated for 30 min at room temperature. The wells were then emptied by tapping the microwell holder upside down vigorously against an absorbent paper (3 times in a row) to ensure complete removal of liquid from the wells. The wells were then filled with 250 µL wash buffer. The wells were again emptied, and this was repeated two more times. One hundred microliters of the substrate were then added to each well and the plate shaken gently to mix the contents. The plate was then incubated for 15 min at room temperature. One hundred microliters of stop solution was then added to each well and absorbance measurements recorded at 450 nm on a multi plate reader (Thermo Electron Corporation Multiskan EX, Waltham, MA, USA). Total aflatoxins levels were calculated using ELISA software (Rida® Soft, Z9999, R-Biopharm AG, Darmstadt, Germany).

## 2.7. Data Analysis

Aflatoxin levels in maize samples were expressed as the mean  $\pm$  standard deviation and students' t-test was used for comparison between season 1 and 2.  $p < 0.05$  was considered significant. Moreover, the adjusted wald technique [25] was used to determine the confidence interval for responses provided by farmers in Nandi County.

## 3. Results

### 3.1. Socio-Demographics of Maize Farmers Interviewed in the Study Area

Table 1 is a summary of the socio-demographic profile of farmers in the study area.

**Table 1.** Sociodemographic characteristics of farmers interviewed in the study area.

Variable	Frequency	%
<b>Gender</b>		
Male	38	42.2
Female	52	57.8
<b>Number of Years in Farming</b>		
1–5 years	74	82.2
6–10 years	4	4.4
11–15 years	3	3.3
>15 years	9	10.0
<b>Months When Maize was Planted</b>		
January	22	24.4
March	61	67.7
April	7	7.8
<b>Acreage of Farm</b>		
<1 acre	11	12.2
1–5 acres	65	72.2
5.5–20 acres	14	15.6
<b>An alternative Source of Income</b>		
Yes	54	60.0
No	36	40.0
<b>Reasons for Farming</b>		
Subsistence	24	26.7
Commercial	66	73.3

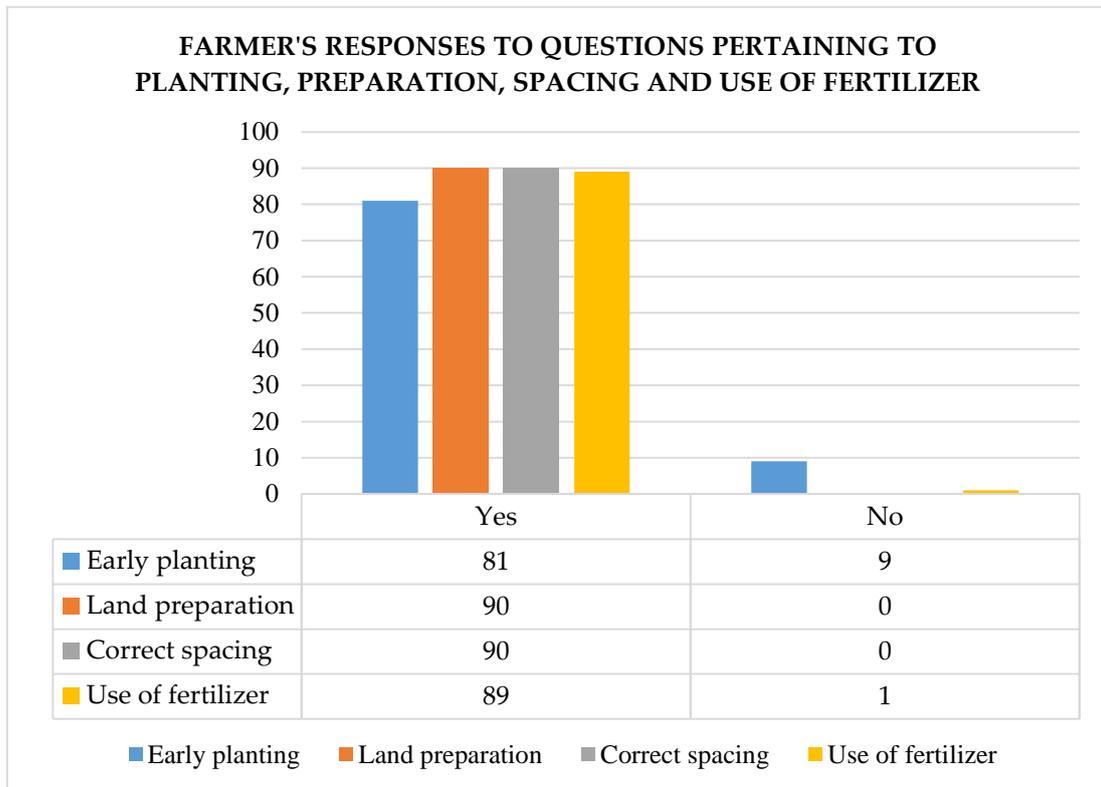
Ninety farmers were interviewed and were drawn from the Kaptumo (23, 25.6%), Kilibwoni (34, 37.8%) and Kipkaren (33, 36.7%) divisions. The distribution of the 90 farmers among the farmer field schools was as follows: 12 (13.3%) from Keteba, 11 (12.2%) from Mwangaza, 18 (20%) from Kisob Katanin, 16 from Toleltany (17.8%), 18 (20%) from Sobetab Gaa, and 15 (16.7%) from Toret Gaa.

### 3.2. Early Planting, Land Preparation, Correct Spacing, and Use of Fertilizer

Figure 2 is a summary of the farmers' responses to questions pertaining to early planting, land preparation, and the use of fertilizer in Nandi County.

Eighty-one (81/90, 90%) of all farmers interviewed in Nandi County carried out early planting at least 3 weeks before the rains. Of the 81 farmers who carried out early planting, 9 were from Keteba, 18 were from Kisob Katanin, 10 were from Mwangaza, 18 were from Sobet Gaa, 16 were from Toleltany and 10 were from Toret Gaa farmer field schools. The 95% confidence interval for responses pertaining to early planting, land preparation, and the use of fertilizer was 0.81 to 0.95, 0.95 to 1.00, and 0.95 to 1.02, respectively. Thus, we estimate that the intent of the farmers in the study area to adopt early planting was between 81% and 95% whereas the intent of all farmers to adopt land

preparation and correct spacing was between 95% and 100%. Moreover, we estimate that the intent of farmers in Nandi county to use fertilizers was between 95% and 102%.

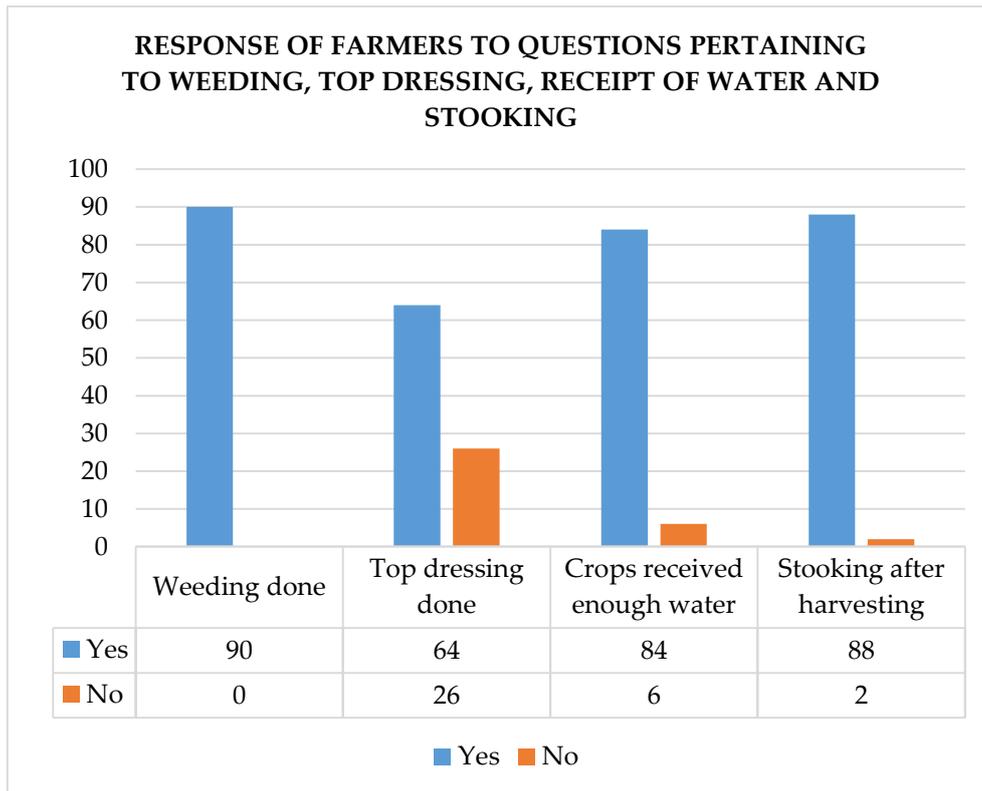


**Figure 2.** Responses to questions pertaining to early planting, land preparation, and the use of fertilizer in the study area.

### 3.3. Weeding, Top Dressing, Stooking, Receipt of Water, and Method of Harvesting

Figure 3 is a summary of the farmers’ responses to questions pertaining to weeding, top dressing, stooking, receipt of water, and the method of harvesting.

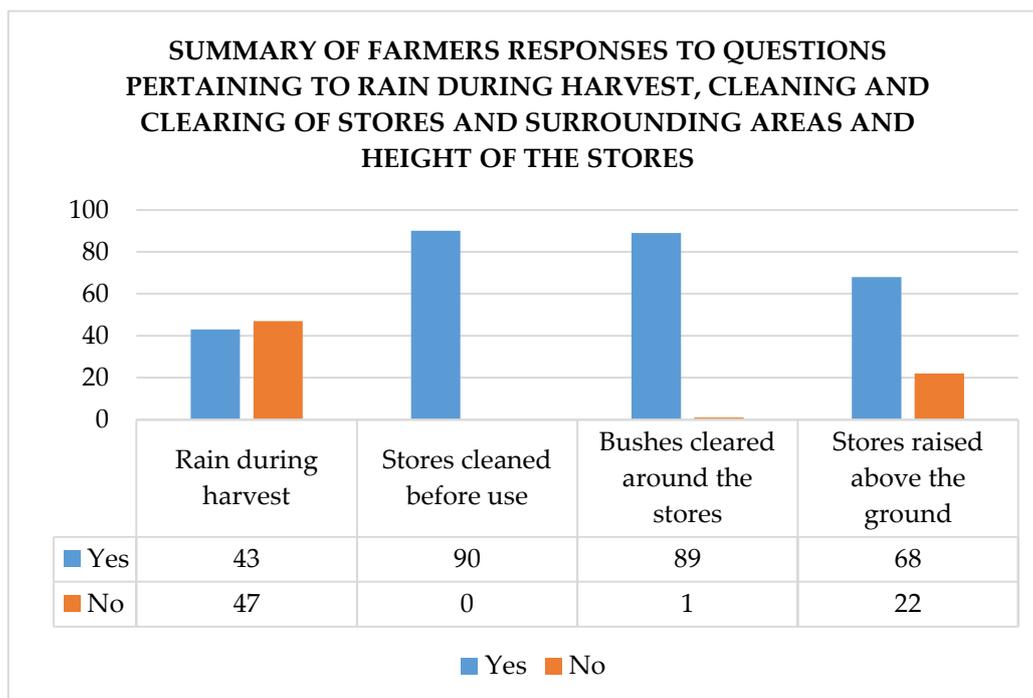
The 95% confidence interval for responses pertaining to weeding, top dressing, whether crops received enough water, and stooking after harvesting was 0.97 to 1.02, 0.61 to 0.79, 0.87 to 0.99 and 0.92 to 1.00, respectively. Thus, we estimate that the intent of farmers in the study area to weed their farms was between 97% and 102%, and between 61% and 79% with regard to their intent to carry out top dressing. Moreover, we estimate that between 87% and 99% of farmers in the study area believed that the crops received enough water. Furthermore, we estimate that the intent of farmers in the study area to carry out stooking after harvesting was between 92% and 100%.



**Figure 3.** Responses to questions pertaining to weeding, top dressing, stooking practices, and the water received by crops in the study area.

*3.4. Rainfall During Harvest, Cleaning of Stores before Use, Clearing of Bushes around the Stores, and Raising of Stores above the Ground*

Figure 4 is a summary of the farmers’ responses to questions pertaining to rain during harvest, cleaning and clearing the bushes around the stores, and the raising of stores above the ground.



**Figure 4.** Responses towards questions pertaining to rain during harvest, cleaning, and clearing of the bushes around the stores, and the raising of stores above the ground.

The 95% confidence intervals for responses related to rain during harvesting, cleaning of stores before use, clearing bushes around the stores, and raising of the stores above the ground was 0.38 to 0.58, 0.97 to 1.03, 0.95 to 1.03 and 0.67 to 0.85, respectively. Thus, we estimate that between 38% and 58% of all farmers in the study area believed that rain occurred during harvesting, between 97% and 103% of all farmers had an intent of cleaning stores before use, between 95% and 103% of farmers had an intent of clearing bushes around the stores, and between 67% and 85% of farmers had the intent to raise stores above the ground.

3.5. Use of Wooden Pallets, Drying of Maize after Harvesting, Checking the Condition of the Mmaize after Harvesting, and Sorting after Shelling

Figure 5 is a summary of the farmers’ responses to questions pertaining to the use of wooden pallets to store maize, drying of maize after harvesting, checking the condition of the maize in the store, and sorting after shelling.

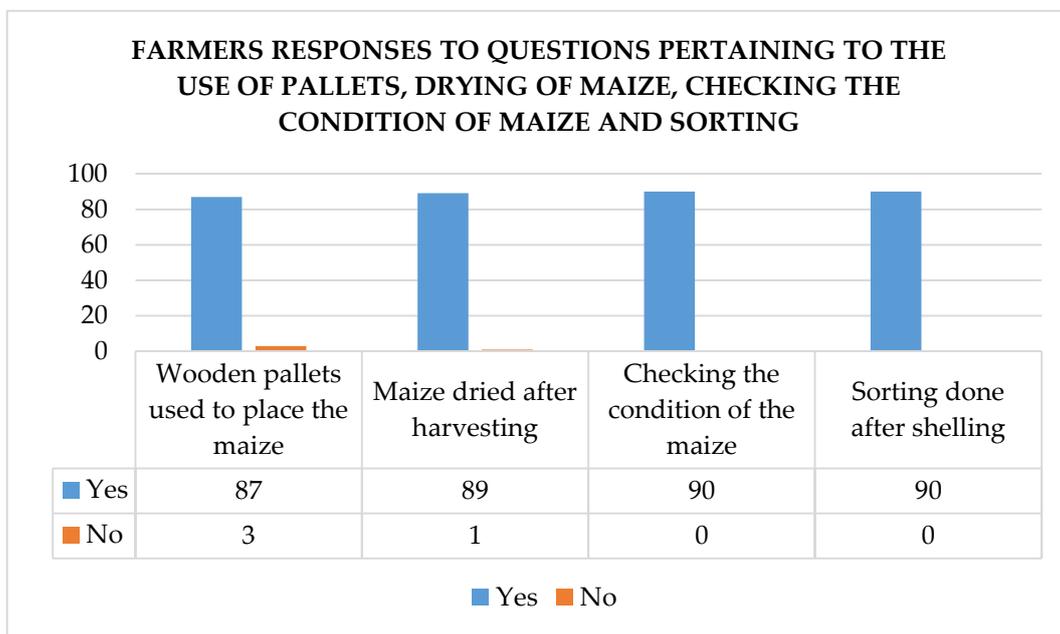
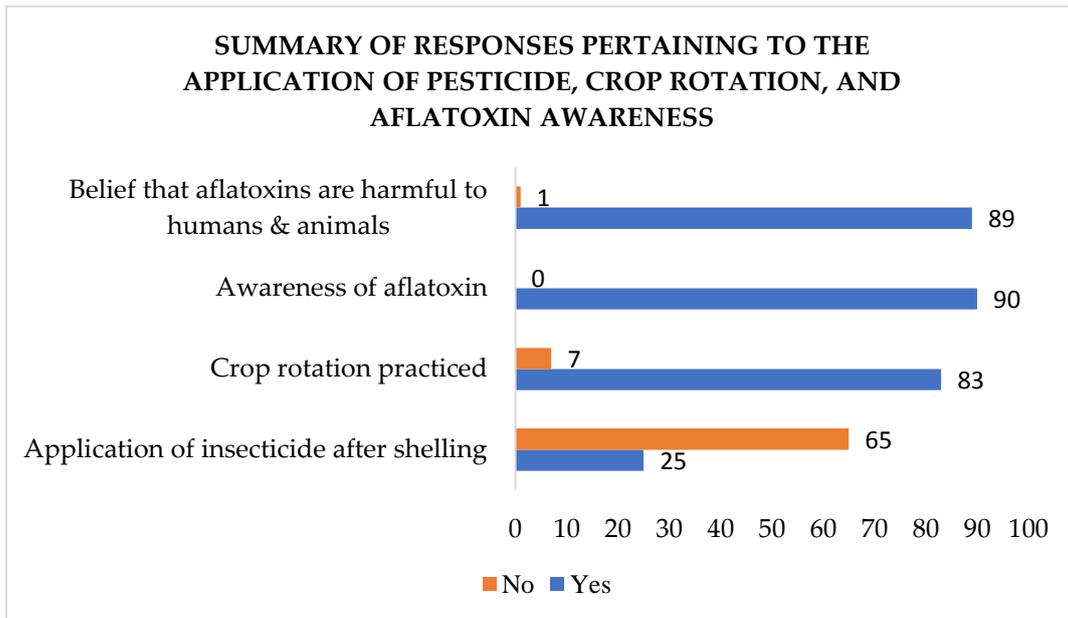


Figure 5. Responses to questions pertaining to rain during harvest, cleaning, and clearing of the bushes around the stores, and the raising of stores above the ground.

The 95% confidence interval for responses to questions pertaining to the use of wooden pallets to place the maize, whether maize was dried after harvesting, whether the condition of the maize was checked after harvesting, and whether sorting was done after shelling was 0.93 to 0.102, 0.95 to 0.103, 0.97 to 0.103, and 0.97 to 0.103, respectively. We estimate that the intent of farmers in the study area to place maize on wooden pallets was between 93% and 102% while the intent to dry maize after harvesting was between 95% and 103%. Moreover, the intent of farmers to check the condition of the maize after harvesting, and sorting maize after shelling was between 97% and 103%, respectively.

3.6. Application of Insecticide after Shelling, Crop Rotation, and Farmers’ Awareness of Aflatoxin

Figure 6 is a summary of the farmers’ responses to questions pertaining to the application of insecticide after shelling, crop rotation, and farmers’ awareness of aflatoxin.

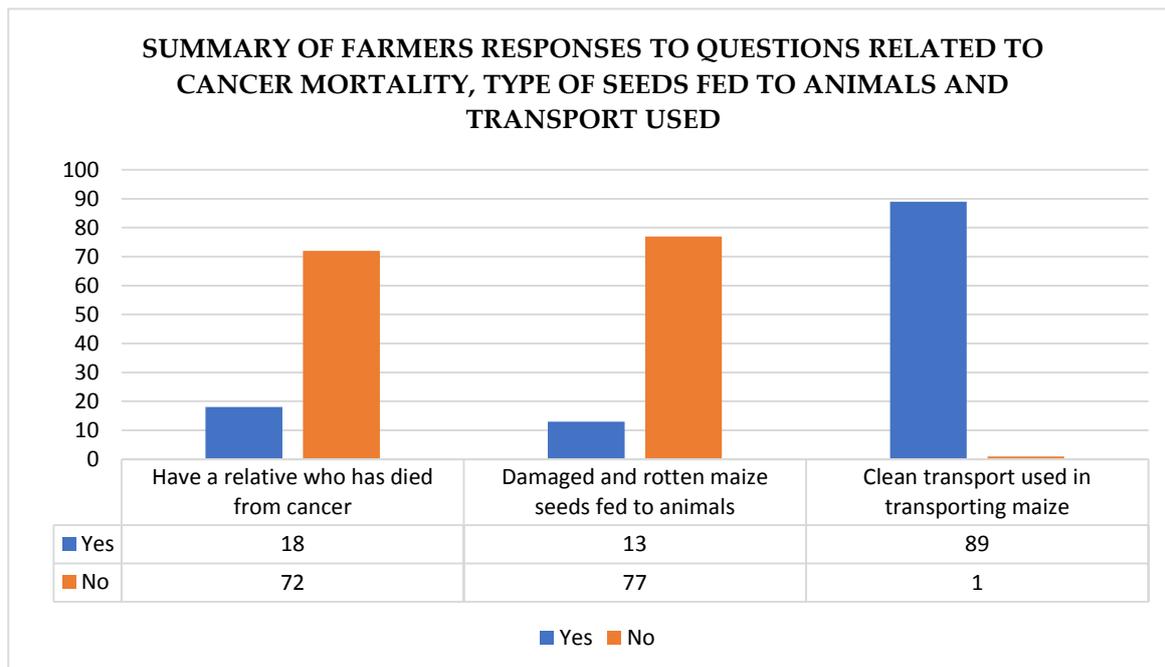


**Figure 6.** Responses to questions pertaining to the application of insecticide after shelling, crop rotation, and farmers’ awareness of aflatoxin.

The 95% confidence intervals for responses pertaining to the application of insecticide after shelling, whether crop rotation was practiced, aflatoxin awareness, and the belief that aflatoxins are harmful to humans and animals were 0.63 to 0.81, 0.84 to 0.96, 0.97 to 0.103, and 0.95 to 0.102, respectively. Thus, we estimate that the intent of farmers to apply insecticide after shelling was between 63% and 81%, and to practice crop rotation was between 84% and 96%.

*3.7. Liver Cancer-Related Death of Farmers’ Relative (s), Feeding Maize Seeds to Animals, and Transport of Maize*

Figure 7 is a summary of the farmers’ responses to liver cancer related mortality, feeding of damaged and rotten maize to animals, and the use of clean transport.



**Figure 7.** Responses to questions pertaining to liver cancer-related mortality, feeding damaged and rotten maize seeds to animals, and the use of clean transport in transporting maize.

The 95% confidence interval for questions related to whether the farmers had a relative who had died from liver cancer, whether the farmers had fed damaged and rotten maize to animals, and the use of clean transport was 0.13 to 0.29, 0.8 to 0.24%, and 0.95 to 0.103, respectively. We estimate that the intent of farmers in the study area to feed damaged and rotten maize seeds to animals was between 8 and 24%, while their intent to use clean transport in transporting maize was between 95 and 103%.

### 3.8. Others

Table 2 is a summary of the distribution of other variables captured in the questionnaire including what farmers said about the nature of the seeds, sizes of the stook (s) used, storage conditions after harvesting, storage facilities used, and the fertilizer used.

**Table 2.** Other variables captured in the questionnaire.

Variable	Frequency (n = 90)	%
<b>Nature of Maize Seeds</b>		
Very dry	11	12.2
Moderately dry	79	87.8
<b>Size of the Stook</b>		
Small	85	94.4
Big	3	3.3
Not done	2	2.2
<b>Storage after Harvesting</b>		
Mat/rack	45	50
On the ground	45	50
<b>Storage Facility Used</b>		
Store	88	97.8
In the house/ground	2	2.2

### 3.9. Mean Aflatoxin Levels

Table 3 is a summary of the mean aflatoxin levels in maize collected from farmers in the different field schools in the study area

**Table 3.** Mean aflatoxin levels in maize sampled from different farmer field schools.

Division	Farmer Field School	N	Range for Season 1	Range for Season 2	Mean for Season 1	Mean for Season 2
Kaptumo	Keteba	20	1.36–3.53	2.75–3.92	2.30 ± 0.74	3.35 ± 0.35 *
	Mwangaza	16	0.794–2.59	0–1.14	1.528 ± 0.448	0.334 ± 0.525 *
Kilibwoni	Kisob Katanin	12	0.993–4.39	0–3.66	3.03 ± 1.10	2.50 ± 0.97 **
	Toletany	9	0.984–4.03	0–3.66	2.586 ± 1.400	0.118 ± 3.53 *
Kipkaren	Sobetab Gaa	15	0–2.94	0–0.884	1.257 ± 0.62	0.172 ± 0.356 *
	Toret Gaa	10	0–1.26	0–0.803	0.842 ± 0.469	0.0803 ± 0.254 *
		<b>82</b>	<b>0–4.39</b>	<b>0–3.92</b>	<b>1.918 ± 1.065</b>	<b>1.301 ± 1.501 *</b>

N: number of farmers, \*: significantly different, \*\*: not significantly different; there was a significant difference in mean aflatoxin levels in maize between season 1 and season 2 in all the farmer field schools with the exception of Kisob Katanin in the Kilibwoni division.

## 4. Discussion

### 4.1. Socio-Demographics of Maize Farmers Interviewed in the Study Area

The statistics behind the practice of agriculture in Kenya are damning. Up to 25% of Kenya's gross domestic product is tied to agriculture with the sector employing a remarkable 75% of the national labor force [26]. Maize is the staple food for most households in Kenya and is mostly produced by small scale farmers [27]. It is also an important livestock feed both as a silage and crop residue [27]. Grains are also used industrially for starch and oil extracts [27].

Our observations that there were more female farmers than male ones in Nandi County bodes well with the narrative perpetuated by Diiro and colleagues who reported that there was a positive correlation between maize productivity in Western Kenya and women's empowerment in agriculture [28]. Our observation that most farmers had an alternative source of income other than maize farming may have something to do with the problems that have been facing maize farmers in Kenya for the last two years. These include drought, army worm infestation, and lack of market access [29]. It could be suggested that farmers in the study area may have begun diversifying their crops given the attendant problems associated with growing maize in the region for commercial gain.

#### *4.2. Practices that Had a 100% Response Rate; Land Preparation, Weeding, Correct Spacing, Cleaning Stores, Sorting Maize after Shelling, Harvesting, and Moisture Content of Harvested Maize Seeds*

Generally, practices such as weeding, checking the condition of maize, and sorting the maize after shelling were well received among the farmers interviewed.

All farmers did land preparation. According to the training manual, land preparation removes crop residues such as old stems that may be lying on the farm and may serve as potential substrates for the growth of fungi responsible for aflatoxin contamination [30]. Moreover, it is noteworthy that all farmers interviewed made use of Kenya seed 6213 which is recommended for this agro-ecological zone. The advantage of this seed is that it produces better yields per unit area than other seed varieties, has a full husk cover which is important as rotting is minimized, and is a moisture and disease resistant variety.

All farmers interviewed practiced weeding on their farms. According to the training manual, weeding is important as it removes substrates which facilitate the growth of mycotoxin-producing fungi. Moreover, weeding makes it so that aflatoxin producing fungi are buried and scattered, thereby greatly reducing the population mass of the fungi and limiting its growth. Moreover, Atehnkeng and colleagues recommend that it is important to undertake timely control of weeds to avoid them competing with the crop. They advise weed control via the use of a hoe, bull, tractor or herbicide [31].

The training manual advocated that correct spacing of seedlings should be 75 × 25 cm. All farmers took well to this aspect of the training. Overcrowding should be avoided, and optimum populations should be established to avoid creating drought stress for the crop [31].

All farmers interviewed cleaned their stores before storing their harvest. According to the code of practice for the prevention and reduction of aflatoxin in tree nuts, cleaning of stores is important as stores that are not clean and dry may facilitate fungal growth during storage [31].

All farmers interviewed reported that they sorted the bad maize from the good maize after shelling. According to the code of practice for the prevention and reduction of aflatoxin contamination in tree nuts [31], sorting of maize is important since aflatoxin producing fungi have a better chance contaminating damaged seeds than good seeds. This is likely to facilitate the contamination of the stored crop with aflatoxin.

All farmers interviewed used the manual method of harvesting rather than the mechanical method. According to the training manual, mechanical damage to the grain during harvesting exposes the seed to contamination due to breakage of the seeds. This is particularly true when poorly calibrated threshers are used [32].

#### *4.3. Practices that Had 85–99% Response Rate; Early Planting, Crop Rotation, Use of Wooden Pallets, Stooking*

About 90% of farmers interviewed reported that they did early planting. According to the training manual, early planting is recommended as crops have been reported to be less affected by

pests, toxins, and disease when planted early as opposed to a late planted crop. In the case of maize, planting exposes the crop to diseases such as maize lethal necrosis disease (MNLN) and maize stalk borer. Atehnkeng and colleagues recommend that planting of crops should be done at the right time to enable crop disease escape and have enough rain for growth and maturity towards the end of the season [32].

About 90% of the farmers interviewed reported to have practiced crop rotation. Crop rotation has been shown to be important in reducing mycotoxin contamination in grains [32]. Also, crop rotation has been reported to reduce aflatoxin prevalence in crops by breaking the cycles and build-up of toxin-producing microorganisms [33]. Notwithstanding, it is quite disconcerting to observe that some farmers did not carry out this important measure. We posit that more should be done to further educate farmers in this region on the importance of this practice. Moreover, according to the training manual, planting the same commodity on a farm for 2–3 consecutive years may make crops susceptible to mycotoxin-producing fungi. It is also recommended that grains particularly maize and wheat should not be used in crop rotation with each other [32].

About 97% of farmers interviewed reported to have used wooden pallets to store maize in their stores. According to the code of practice for the prevention and reduction of aflatoxin contamination in peanuts [34], grain storage bags should be clean and dry and stacked on pallets or a water impermeable layer should be incorporated between the bags and the floor [34].

About 85% of all farmers interviewed reported that the size of their stook was small. According to the training manual, it is important for the size of the stook to be small to facilitate free air circulation. In West Africa, the practice of stooking is also referred to as heaping [32]. It is advised that not only should the heaps/stooks remain erect in the form of a cone, but also the heaps should not be too big or fall on the ground as they are likely to accumulate moisture at their center [32]. Moreover, it is advised that heaps that have been lying on the ground for long or those with signs of animal/insect damage should not be heaped/stooked [32].

About 88% of the farmers interviewed reported that the harvested maize was moderately dry. Atehnkeng recommends that maize should be dried to less than 13% moisture content without delay. However, since we did not measure the moisture content of the seeds harvested, it is difficult to know exactly how much moisture was in the seeds.

#### *4.4. Practices that Had 50% and <50 % Response Rate; Rain during Harvesting, Storage of Maize, Fertilizer Use, Liver Cancer Related Mortality, Insecticide Use, Positioning of Stores, Feeding Rotten/Damaged Seeds to Animals*

Reports of rain during harvesting by up to 50% of farmers in the area should be a cause of concern. A previous report on mortality associated with acute aflatoxicosis reported that the toxic contamination of maize may have taken place during a period when the maize harvesting season was blighted by heavy rains [18].

About 50% of the farmers interviewed had reported storing maize on the ground after harvesting rather than on a mat or rack. This may have potentially exposed the crop to the soil which may have been carrying the *Aspergillus* fungi and may have facilitated aflatoxin contamination.

According to Atehnkeng and others, crops grown under stress are more susceptible to infestation by the aflatoxin-producing fungi that cause contamination [31]. According to the same author, applying fertilizer and other key inputs reduces crop stress [31]. In our study, about 44% of the farmers interviewed reported using the 75 kg bag of fertilizer per acre recommended by the training manual while about 52% reported using less than the recommended amount per acre. Another 3% reported using the 100kg bag of fertilizer. Further research on the effect of the amount of fertilizer used per acre on aflatoxin levels in maize is warranted.

About 20% had reported that they knew a relative who had died of liver cancer. Though associations have been drawn between aflatoxin exposure and the risk of liver cancer [34], it is difficult to assert whether the person (s) the farmers were referring to had liver cancer as a result of feeding on aflatoxin contaminated maize or whether the liver cancer developed as a result of other factors. Further work is needed to shed more light on this observation.

A paltry 28% of farmers applied insecticide to the harvested crop after shelling. Atehnkheng [31] advises that it is important to control insects particularly the stem borer as insects may damage the crop leading to invasion by aflatoxin causing fungi. Moreover, Nesci and colleagues [35,36] have reported that insects may act as vectors for aflatoxigenic fungi and not using insecticide may open up an avenue for aflatoxin contamination of harvested maize.

Only 24% of the farmers interviewed reported that they did not have stores that were raised above the ground. This is potentially problematic as failure to raise the stores above the ground may be increasing exposure of the harvested crop to soil containing fungi and could also improve the access of rodents to the harvested crop [37]. This access may lead to breakage of the maize seeds which could make it easier for aflatoxin producing fungi to contaminate the maize [37].

About 14% of the farmers interviewed reported that they fed damaged and rotten maize seeds to animals. *Aspergillus* infection has been shown to occur in broken and damaged kernels [2]. Thus, feeding animals with such seeds may expose them to aflatoxin poisoning. This observation implies that despite acknowledging that they were aware of aflatoxins and the damage it causes to human and animal kind, it was lost on farmers that feeding animals on rotten maize may have been unnecessarily exposing them to harm. It is important to note that the food and drug administration has developed guidelines for acceptable aflatoxin levels in maize based on intended use. Based on these guidelines, levels of <20 ppb, <20 ppb, <100 ppb, <200 ppb, and <300 ppb are considered appropriate for young animals, dairy cattle, breeding meat cattle/swine/mature poultry, finishing swine, and finishing cattle, respectively [34].

#### 4.5. Confidence Intervals on the Response of Farmers in Nandi County

Questions pertaining to rain during harvest and feeding damaged and rotten seeds to animals had the lowest confidence intervals. In order to maintain or even lower the observed aflatoxin levels in maize grown in Nandi County, future training on GAP may need to focus on improving these aspects of GAP training. On the other hand, questions pertaining to weeding, whether crops received enough water, the practice of stooking after harvesting, cleaning stores before use, clearing bushes around the stores, the use of wooden pallets, drying of maize after harvesting and checking the condition of the maize after shelling had the highest confidence intervals. This suggests that these aspects of GAP training appear to have been well received by farmers in the study area.

#### 4.6. Mean Aflatoxin Levels

In the 1st season, about 3 samples from an equivalent number of farmers had an aflatoxin level of 0 while in season 2 up to 55 samples from an equivalent number of farmers had an aflatoxin level of 0. This may suggest that the training on good agricultural practice seems to be paying off. It may be conjectured that if the farmers are to continue applying what they learnt from the training, more samples are likely to record similar aflatoxin levels. Furthermore, the action level for aflatoxin-contaminated grains set by the Kenya Bureau of Standards is 10 ppb [38]. It is interesting to note that the levels of aflatoxin in the maize sampled from the farmers were all well below acceptable levels. This appears to be further evidence that the training was well received among the farmers.

Farmers from the farmer field school in Keteba (Kaptumo division) reported that it rained for six months while the crop of maize was in the field in Season 2. This may explain why this was the only farmer field school that had mean aflatoxin levels that were higher in the second season than the first season. A previous study reported that aflatoxin levels in maize were significantly associated with agro-ecological zones and that humidity played a big part in the overall aflatoxin levels [38]. This may be the reason behind the observation of an increase rather than a decrease in aflatoxin levels of maize sampled from this area.

Our findings on the mean aflatoxin levels were comparable to those of Kang'ethe and co-workers who reported baseline values of 0.997 ppb [15]. Moreover, the mean aflatoxin levels we have reported for both seasons were lower than the mean aflatoxin levels of 2.3 ppb reported by Mutiga and others in maize sampled from storage sheds and mills in Nyanza, Rift Valley, and Western Kenya [39]. This

also may be further evidence that indeed training farmers on good agricultural practice may be having positive effects of lowering the aflatoxin levels in maize grown in the region.

### 5. Conclusions

Our findings suggest that some components of the training were better received and practiced by the farmers in Nandi County than others. Aflatoxin levels in maize evaluated before and after the training appear to suggest that training farmers on good agricultural practice may be an important tool in minimizing aflatoxin exposure in maize. Further engagement with farmers is needed especially with regard to the practices that were not very well received. Continued monitoring of aflatoxin levels in maize in the region should be encouraged. We also recommend that a similar strategy is adopted in other maize growing regions in the country.

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### Appendix A

#### Appendix A.1. Kaptumo Division

**Table A1.** Paired Samples Statistics.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	SEASON 1	2.2965	20	0.73593	0.16456
	SEASON 2	3.348	20	0.35262	0.07885

#### Appendix A.1.1. Keteba

**Table A2.** Samples Test.

		Paired Differences				t	df	Sig. (2-tailed)	
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference					
				Lower	Upper				
Pair 1	SEASON 1–SEASON 2	-1.0515	0.79535	0.17785	-1.42374	-0.67926	-5.912	19	0

Appendix A.1.2. Mwangaza

**Table A3.** Samples Statistics.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	SEASON 1	1.528375	16	0.448029	0.112007
	SEASON 2	0.334375	16	0.525335	0.131334

**Table A4.** Samples Test.

		Paired Differences					T	Df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	SEASON 1–SEASON 2	1.194	0.784256	0.196064	0.776099	1.611901	6.09	15	0

**Table A5.** Sample Correlations (Kaptumo division).

Study area		N	Correlation	Significance
Keteba	Pair 1 SEASON 1 & SEASON 2	20	0.064	0.788
	Pair 1 SEASON 1 & SEASON 2	16	-0.294	0.269

**Appendix B**

*Appendix B.1. Kilibwoni division*

Appendix B.1.1. Kisob Katanin

**Table A6.** Samples Statistics.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	SEASON 1	3.02775	12	1.103804	0.318641
	SEASON 2	2.496667	12	0.966365	0.278965

**Table A7.** Samples Test.

		Paired Differences					T	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	SEASON 1–SEASON 2	0.531083	1.046321	0.302047	-0.13372	1.195884	1.758	11	0.106

Appendix B.1.2. Toletany

**Table A8.** Samples Statistics.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	SEASON 1	2.586	9	1.399919	0.46664
	SEASON 2	0.1178	9	0.35333	0.11778

**Table A9.** Sample Correlations (Kilibwoni division).

Study area		N	Correlation	Significance
Kisob Katanin	Pair 1 SEASON 1 &SEASON 2	12	0.496	0.101
Toleltany	Pair 1 SEASON 1&SEASON 2	9	-0.369	0.329

**Table A10.** Paired Samples Test.

		Paired Differences					T	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	SEASON 1- SEASON 2	2.468222	1.565011	0.52167	1.265249	3.671196	4.731	8	0.001

**Appendix C**

*Appendix C.1. Kipkaren division*

Appendix C.1.1. Sobetab Gaa

**Table A11.** Paired Samples Statistics.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	SEASON 1	1.2572	15	0.617218	0.159365
	SEASON 2	0.171733	15	0.355619	0.09182

**Table A12** Paired Samples Test.

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	SEASON 1- SEASON 2	1.085467	0.686961	0.177373	0.70504	1.465893	6.12	14	0

Appendix C.1.2. Toret Gaa

**Table A13.** Paired Samples Statistics.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	SEASON 1	0.8421	10	0.468907	0.148281
	SEASON 2	0.0803	10	0.253931	0.0803

**Table A14.** Sample Correlations (Kipkaren division).

Study area		N	Correlation	Significance
Sobetab Gaa	Pair 1 SEASON 1 &SEASON 2	15	0.081	0.774
Toret Gaa	Pair 1 SEASON 1&SEASON 2	10	0.253	0.48

Table A15. Paired Samples Test.

Pair	SEASON 1– SEASON 2	Paired Differences				T	df	Sig. (2-tailed)	
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower				Upper
1		0.7618	0.473348	0.149686	0.423187	1.100413	5.089	9	0.001

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