Journal of
Agriculture Policy
(JAP)

The Long-Term Influence of the Training on Good Agricultural Practices in Nandi County, Kenya

CARI Journals

Journal of Agricultural Policy
ISSN: 2520-7458 (Online)
Vol.8, Issue No.2, pp 15 – 29, 2025 www.carijournals.org

The Long-Term Influence of the Training on Good Agricultural Practices in Nandi County, Kenya

[1*]Daniel Nyukuri Kwoba, [1]James Mucunu Mbaria, [1]Isaac Mpapuluu Ole-Mapenay, [2]Irene Thiguku Kamanja, [1]Penina Ateku

[1]Department of Public Health, Pharmacology and Toxicology, University of Nairobi, Nairobi, Kenya

[2]Department of Public Health, Pharmacology and Toxicology, Egerton University, Nakuru, Kenya

https://orcid.org/0000-0001-5459-456X

Accepted: 20th Feb, 2025, Received in Revised Form: 24th Mar, 2025, Published: 4th May, 2025

ABSTRACT

Purpose: This study made comparisons on the state of Knowledge, attitude and practices of the trained farmers for the year 2017 against the same cohort in the year 2023 with an aim of evaluating the long-term influence of agricultural training in maize farming in Nandi County Kenya. The study also evaluated the state of Knowledge, attitude and practices of the same trained farmers against untrained farmers by the end of the year 2023.

Methodology: A previous study was followed up in the year 2023 to evaluate the role and a six-year long-term influence of the training on the practices. The data was collected through farm interviews. The positive responses of the practices obtained from the administered questionnaires were recorded. A comparison was then made for the responses on the use of twenty Agricultural practices by the trained farmers in the year 2017 and 2023 and also the same responses of the 30 trained farmers against 30 other untrained farmers by the end of the year 2023.

Findings: The results were analyzed for significant differences based on the relationships of the independent variables by using descriptive statistics, proportion of means. No significant difference was detected in either of the approaches. The analyses of the practices between the trained farmers and untrained farmers showed no significant difference with $p > 0.05$. A general decline in the adoption of the practices from 91.15% to 81.3% between the years 2017 and 2023 was noted. Poor harvesting and post-harvesting operations during sorting and drying of maize that could enhance aflatoxin infections in the maize value chain were also noted.

Unique Contribution to Theory, Practice and Policy: The study comprises of a mixture of theories. The theory of planned behavior, the innovation itself and diffusion of Innovation theory and technology acceptance, played a big role in evaluating the changes in attitude, long-term influence of the training and time needed to propagate the knowledge gained from the training. The influence of climatic, environmental conditions, and socio-economic factors pose challenges to food safety and food security in general. If these factors are not checked regularly to enhance good farming practices, the elaboration of toxins and the occurrence of various mycotoxicosis in both animals and human beings will be high. Therefore, regular farm training is recommended during every planting season to improve consistence in GAP application and mycotoxin mitigation.

Keywords: *Food Safety, Extension Services, Food Security, Maize Value Chain, Farm Practices*

INTRODUCTION

Maize is a staple food consumed by most households in Africa. On average, an African adult consumes about 400g/person/day of maize-based foods, compared to less than 10g/person/day in developed countries, and trends project that the production and use of maize will continue to grow (FAO, 2019).

Importantly, maize is susceptible to fungi that produce aflatoxins (CAST, 2019), which is a significant health concern for humans and livestock (Magnussen & Parsi, 2013). Damaged or discolored maize grains sold to brew makers potentially perpetuate the contamination cycle. Studies in South Africa and Botswana confirm that advanced brewing methods fail to remove toxins from liquor (Nkwe *et al*., 2005a; Shephard *et al*., 2005) and similar studies in Kenya detected fumonisins and other mycotoxins in beer (Mbugua & Gathumbi, 2004a). Kenya has had several aflatoxin outbreaks leading to fatal aflatoxicosis and other diseases, such as liver cancer (Okioma, 2008; Probst *et al*., 2007). Aflatoxin contamination negatively impacts health, trade, and the general economy (Ezekiel *et al*., 2019).

Poor agricultural practices promote fungal growth and toxin production in maize. Given that maize is susceptible to contamination both before and after harvest (Hell, Cardwell, Setamou, & Poehling, 2000), training farmers in hygiene and Good Agricultural Practices (GAPs) throughout food production is essential (Omara, 2021). The susceptibility to fungal contamination can be lowered by using various pre-harvest practices like early planting, planting genetically modified disease-resistant cultivars, weeding, proper plant spacing, crop rotation, using fertilizers and manure, and intercropping (Bruns, 2003; Diener *et al*., 1987; Finckh, 2008; Kang'Ethe *et al*., 2017; Kebede *et al*., 2012; Liebman & Dyck, 1993; Logrieco *et al*., 2021; Mutiga *et al*., 2014).

Similarly, post-harvest practices, such as careful harvesting, proper drying, stoking, sorting and destroying maize with high moisture content, not exposing kernels to ground-level contamination, crop rotation, and removing crop residues reduce the risks of infection (Blandino *et al*., 2008; Bruns, 2003; Demissie, 2018; Fandohan *et al*., 2005, 2006; Hawkins *et al*., 2005; Heathcote *et al*., 1978; Hell, Cardwell, Setamou, & Schulthess, 2000; Liu *et al*., 2016; Manu *et al*., 2019a; Marete *et al*., 2019; Massomo, 2020; Munkvold, 2003; Mutiga *et al*., 2019; Sumner & Lee, 2017; Turner *et al*., 2005; Udoh *et al*., 2000; Zummo, 1992). In particular, high humidity (>70%) and plant moisture content above 13% exacerbate the risk of infection (Wagacha & Muthomi, 2008). Overall, checking and ensuring Good Agricultural Practices reduces aflatoxin contamination in farm produce. A follow up study was done on a previous study that examined how training farmers in GAPs impacted aflatoxin contamination in maize (Marete *et al*., 2019). The study involved 90 farmers trained in GAP techniques in Nandi County, Kenya, over two planting seasons in 2016-2017(Marete *et al*., 2019). In this study, most farmers had adopted key practices, including proper storage, crop rotation, early planting, and thorough sorting of maize after shelling. These practices significantly reduced aflatoxin levels, with many samples recording levels that were below detectable limits in the second season. Additionally, increased rainfall during harvest in some areas negatively impacted aflatoxin levels. The study suggested that GAP training can reduce aflatoxin levels in maize, but the variability in adoption due to socio economic factors, climatic and environmental conditions suggested that tailored interventions would be helpful. Whether GAPs persisted over time was not clear. To this end, we performed a follow-up study to evaluate GAPs in Nandi County, Kenya.

MATERIAL AND METHODS

Ethical approval

The study was approved by the Animal Use, Biosafety, and Ethics Committee in the Faculty of Veterinary Medicine within the University of Nairobi, approval no: FVM BAUEC/2023/45 dated November 2, 2023. Additionally, a research permit was obtained from the National Commission for Science Technology and Innovation (NACOSTI) under License No. NACOSTI/P/24/35010 to conduct research in Nandi County.

STUDY DESIGN

Reconnaissance

A pre-visit was carried out to introduce our study to the locals and to identify the previous cohort of trained farmers. Each respondent was briefed on the study's objective and then asked for oral consent.

Sample size determination

The current study included a total of 60 farmers; a random selection of 30 previously trained farmers whose maize samples had been analyzed (Marete *et al*., 2019), and a group of 30 farmers who were not formally trained (control). The three regions included Kaptumo (n=20), Kipkaren (n=20) and Kilibwoni (n=20) which had been subdivided into Mwangaza (n=10), and Keteba (n=10), Sobetab Gaa (n=10) and Toret Gaa (n=10) and Kisob Katanin (n=10) and Toletany (n=10), respectively (Fig. 1). Five trained farmers were randomly interviewed for every substation, corresponding to 30 farms that represent the six sub-regions. The long-term influence of the training was evaluated by applying two approaches: Compared 20 GAPs for 1) 90 trained farmers in 2017 against 30 trained farmers of the same cohort in 2023, and 2) 30 trained farmers to 30 untrained farmers in 2023.

Journal of Agricultural Policy
ISSN: 2520-7458 (Online)
Vol.8, Issue No.2, pp 15 – 29, 2025

Study Area

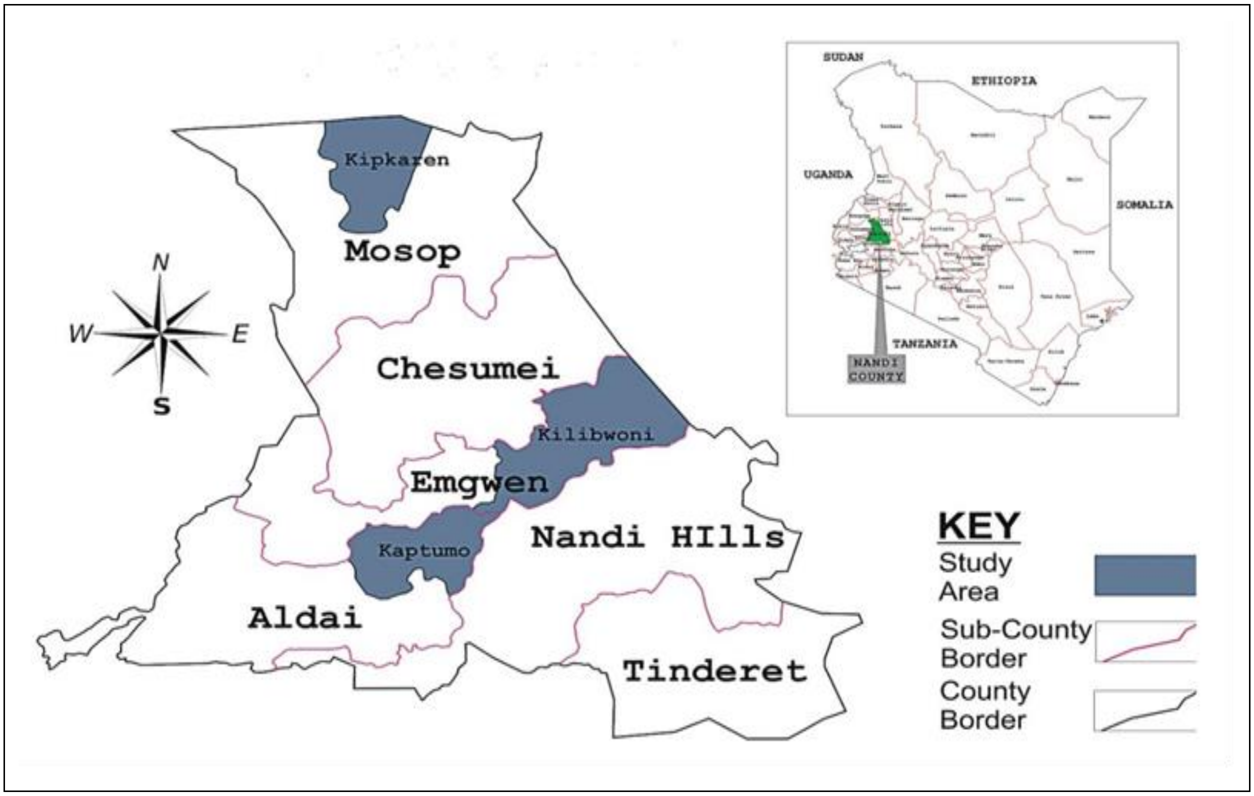

Figure 1: A map of Kenya Showing Nandi County and the selected farms for study (Adopted from Marete *et al*., 2019)

Data Collection

We designed a survey of 40 questions to capture data on

a). Socio-Demographic Information: This section contained 11 questions on the gender, farmer's location, years practiced maize farming, acreage of the farms, land sold, leased, or passed on through inheritance, and whether a trained farmer had died or relocated to other counties.

b). Good Agricultural Practice; This section contained 29 questions that included inquiries on spacing, early planting, use of fertilizer, weeding, water availability, crop rotation, effects of rainfall, cleaning of stores before use, clearing of bushes around the stores, raised stores above the ground, maize placed on wooden pallets, maize dried after harvesting, checking the condition of maize, sorted maize after shelling, application of insecticide after shelling, nature of transport and maize fed to animals(Marete *et al*., 2019). Other questions included the mode of disposal of unfit maize grains and how moisture content was measured.

Data Analysis and Processing

Hypothesis testing to compare two sample proportions for significant differences of the farming practices.

To determine the significant difference in proportions at a confidence interval of 95%, a two-sample z-test for proportions was performed as shown in the steps:

Defined the hypotheses; (H_1) and (H_0):

- H_0: $p_1 = p_2$ (the sample proportions are equal), H_1: $p_1 \neq p_2$ (the sample proportions are not equal)

The pooled sample proportion (P) was calculated:

$P (n_1 + n_2) = (X_1 + X_2)$

Where n_1 and n_2 represent the sample sizes and X_1 and X_2 represent the number of successes in each sample.

Calculated the standard error (SE):

$SE = \sqrt{\{(P-P^2) * (1/n_1 + 1/n_2)\}}$

Z-score was calculated: $Z/ SE = (p_1 - p_2)$

The critical value at a 95% confidence interval (alpha = 0.05) was determined using a standard normal distribution table. For a two-tailed test, the critical values are approximately ±1.96.

The absolute/calculated value, |Z| of the z-score was compared to the critical value using the following assumptions:

If $|Z| > 1.96$, The null hypothesis is rejected and conclude that there is a significant difference between the two proportions.

If $|Z| \leq 1.96$ The null hypothesis is upheld and conclude that there is not enough evidence to support a significant difference between the two proportions (Connor & Imrey, 2014; Daniel, 2009; Sauro & Lewis, 2012).

RESULTS

In 2023, three regions (shown in the Map figure 1) were revisited to identify farmers who were interviewed and trained in 2016-2017(Marete *et al.*, 2019). Out of the 90 farmers evaluated by Marete et al (2019), only 45 were found in their original maize farm locations, with their pieces of land intact. The remaining 45 had sold, leased out, or transferred their land through inheritance or had died from COVID-19. Of these 45 farmers, only 33 were still growing maize, whereas 12 had changed to tea farming, claiming that it had become more lucrative than maize.

PART 1: COMPARISON OF GOOD AGRICULTURAL PRACTICES BETWEEN TRAINED FARMERS IN 2017 AND 2023

The proportions of trained farmers after applying the 20 surveyed GAPs were 91.15% in 2017 and 81.3% in 2023 (Table 1). To compare these proportions, a Z test with a significance level of p>0.05. The Z statistic was calculated and compared with the critical value of ±1.96, which corresponds to a 95% confidence level (Connor & Imrey, 2014; Daniel *et al*., 2009; Sauro & Lewis, 2012). The calculated Z statistic was 1.345, which falls within the range where we fail to reject the null hypothesis.

Table 1: Comparison of GAPs applied by trained farmers from 90 farms in 2017 and 30 farms in 2023

No	Good Agricultural Practices	Positive responses: Trained farmers, 2017 (Marete *et al*., 2019) (n=90, converted to 100%)	Positive responses: Trained farmers, 2023 (n=30 converted to 100%)
1	Correct spacing	100	100
2	Early Planting	90	100
3	Use of fertilizers and fungicides	99	100
4	Land Preparation	100	97
5	Weeding	100	97
6	Top dressing	71	86
7	Crops received enough water (Irrigation)	93	93
8	Crop rotation Practiced	92	83
9	Stocking after harvesting	98	80
10	Maize not affected by rain during harvest	52	40
11	Cleaned stores before use	100	70
12	Cleared bushes around the stores	99	70
13	Raised stores above the ground	76	57
14	Maize placed on wooden pallets	97	27
15	Maize dried After harvesting	99	100
16	Checking the condition of the maize	100	100
17	Sorted maize after shelling	100	100
18	Application of Insecticide after shelling	72	67
18	Animals fed on clean and undamaged maize	99	86
20	Use of clean transport of maize (2017-2023)	86	73

Total positive responses	**1823**	**1626**
Overall % positive responses of Good Agricultural Practices	**91.15**	**81.3**

PART 2: COMPARISON OF GOOD AGRICULTURAL PRACTICES BETWEEN TRAINED AND UNTRAINED FARMERS IN 2023.

Overall responses for proportions of trained and untrained farmers after applying the 20 surveyed GAPs were 91.15% in 2017 and 81.3% in 2023 respectively (Table 2). Again, we used a Z test with $p>0.05$ to determine whether training impacts the application of GAPs (Connor & Imrey, 2014; Daniel, 2009; Sauro & Lewis, 2012). The Z statistic was 0.205, less than the critical value of – or + 1.96, so we upheld the null hypothesis. Therefore, there is insufficient evidence to conclude that a difference exists between trained and untrained farmers.

Table 2: Comparison of GAPs between 30 trained farmers and 30 untrained farmers in randomly selected farms in 2023

No	Good Agricultural Practices	Positive responses: Trained Farmers (n=30)	Positive responses: Untrained farmers (n=30)
1	Correct spacing	30	29
2	Early Planting	30	28
3	Use of fertilizers and fungicides	30	28
4	Land Preparation	29	29
5	Weeding	29	30
6	Top dressing	26	25
7	Crops received enough water (Irrigation)	28	30
8	Crop rotation Practiced	25	26
9	Stocking after harvesting	24	22
10	Maize not affected by rain during harvest	12	7
11	Cleaned stores before use	21	21
12	Cleared bushes around the stores	21	21
13	Raised stores above the ground	17	21
14	Maize placed on wooden pallets	8	9
15	Maize dried After harvesting	30	28
16	Checking the condition of the maize	30	30
17	Sorted maize after shelling	30	29
18	Application of Insecticide after shelling	20	22
18	Animals fed on clean and undamaged maize	22	15
20	Use of clean transport of maize (2017-2023)	26	24
	Total positive responses	**488**	**474**
	Overall % positive responses of Good Agricultural Practices	**81.3%**	**79%**

We did notice that some GAPs were used more often by the untrained farmers than the trained farmers, such as Weeding, irrigation, crop rotation, use of wooden pallets, maize condition checks, raising stores above the ground and application of insecticides. In contrast, trained farmers applied other GAPs more often, such as feeding livestock with clean and undamaged maize, and maize not being affected by rain during harvest.

In the interview, many households reported that damaged or discolored maize grains, were being fed to livestock or sold to brew makers. Similarly, leftover maize grains in the field, which had been exposed to the ground, were collected, hand-shelled, and sold to brew makers or fed to livestock. In addition, we found that some farmers estimated moisture content by biting maize kernels, or puncturing them with their thumbnails or teeth.

Discussion

The current study is a follow up on what Marete and others did in the year 2016 & 2017; They Interviewed 90 farmers who had been trained on Good Agricultural Practices but analyzed 82 samples for total aflatoxin levels before and after the training (Marete *et al*., 2019). This study set out to investigate a six-year long term influence of the training and its role on the farming practices in maize farming zones in Nandi County, Kenya.

A comparison was made on twenty practices between this study and the previous study. Out of the twenty practices used by the 90 farmers in the year 2017, the overall adoption percentage was 91.15% against 81.3% of the 30 farmers in the year 2023. A comparison in the proportions of the practices using Z test (Connor and Imrey, 2014; Daniel *et al*., 2009; Sauro and Lewis, 2012) between trained farmers in the year 2017 and 2023 showed no significant difference with $p>0.05$. In addition, a general decline in the application of the practices from 91.15% to 81.3% was also noted.

During the reconnaissance it was also established that some of these farmers had either sold, leased out or transferred the pieces of land through inheritance to family members that had not been trained. Some farmers had also relocated to other counties or passed on due to Covid 19. It was also established that some of these farmers had changed completely to tea farming which was claimed to generate quick income. As such a smaller sample size was obtained that was not statistically representative and comparable to the initial sample size in the previous study. This small sample size of 33 farmers compromised the statistical significance of our study, and hence our inability to determine the long-term influence of the training that was to be based on the sample size (Daniel *et al*., 1999; Lachenbruch *et al*., 1991). A speculation in this indicate that an early follow-up would have enabled a representative sample size of farmers, if not the entire cohort. A six year-long term influence of the training was therefore influenced by the socio-economic factors. Perhaps if an immediate follow-up study had been conducted in the year 2018, this approach would not have experienced such limiting factors. The finding in the reconnaissance study therefore calls for frequent follow ups to ensure that there is consistent Good Agricultural Practices application so as to maintain low level of aflatoxins.

In the second approach, the sample size for trained farmers was 30 with an overall positive response of 81.3% against 79% of the same number of untrained farmers in 2023. A comparison in the proportions of the mean of the practices between trained farmers and untrained farmers by the year 2023 showed no significant difference with $p>0.05$ (Connor and Imrey, 2014; Daniel *et al*, 2009; Sauro and Lewis, 2012). During the interview, it was also alluded that during post-harvest operations, accidentally left overs of maize that are already exposed onto the ground are collected, hand shelled for sale or consumed instead of being discarded (Bryceson and Howe, 1992). Mechanically damaged or colored maize grains which are unfit for consumption and therefore ought to be destroyed (EAS, 2011) are instead given to livestock or sold out to brew makers. Proper drying of maize to moisture levels of ≤13% during storage, transportation and sales is essential to prevent growth of fungi (Wagacha and Muthomi, 2008). Some of the local practices used by the farmers to estimate moisture content included biting kernels or puncturing with their thumbnail or teeth when the recommended method is by use of moisture content meter that ensure the safe limits of about 13% is maintained (Liu *et al*., 2016; Manu *et al*., 2019b). Therefore, since all pre-harvest and post-harvest operations are susceptible to aflatoxins contamination, there is need to monitor aflatoxins levels at multiple points in maize production, from the farm to the table so that it does not exceed the regulatory limits of 10ppb set by Kenya Bureau of Standards and East Africa Community (KEBS, 2018*;* Muthomi *et al., 2009;* Winfred *et al*., 2022).

From the findings some of the practices were perceived more by the untrained farmers than the trained farmers as indicated in the responses on weeding, correct spacing, raising of stores, use of wooden pallets, maize condition checks and application of insecticide after shelling. This could have been attributed by the diffused training between the trained and untrained farmers. Therefore, moving forward, there is need for immediate follow up in these maize farming zones to clearly monitor the aflatoxin levels so as to ensure that there is consistent use of Good Agricultural Practices to realize the role of Agricultural training.

Poor post-harvest management practices and ignorance for mycotoxins exposure pose potential health risks to the consumer (Koskei *et al*., 2022b). Training and all forms of sensitization on hygiene and Good Agricultural Practices should therefore be encouraged at all multiple points of food production. This has been confirmed that inadequate sensitization and low education levels are the cause to the spread of aflatoxins in Kenya (Omara *et al*., 2021). Aflatoxins are resistant to heat and can withstand normal cooking temperatures (Yau *et al*, 2018). On the other hand, even these advanced methods used to make brews hardly remove all the toxins in the liquor (*Nkwe et* *al.*, 2005b; Shephard *et al*., 2005). A good example is case study in Kenya where mycotoxins were isolated in beer (Mbugua and Gathumbi, 2004).

CONCLUSION

Although the application of GAPs appeared had a slight decrease between trained farmers in the years 2017 and 2023, no significant difference was detected in either of the approaches to confirm that indeed the training did not have a long-term influence. During the interview, it was also alluded that during post-harvest operations, accidentally left overs of maize that are already exposed onto the ground are collected, hand shelled for sale. It was also noted that the sorted maize kernel whose condition is unfit for consumption is given to livestock or sold to brew makers. Only 33 of the 90 trained farmers in Nandi County were found in the same maize farm locations, after a six years period. This decrease in the cohort limited our analysis for the long-term influence of training and suggests that more frequent follow-up is needed for a prospective analysis of farming practices. Trends in our data suggest that GAP application by trained farmers deteriorates slightly over time and that trained and untrained farmers display relatively similar adoption in GAPs. A general decline in the adoption of the practices from 91.15% to 81.3% between the years 2017 and 2023 was noted. Diffused training was also part of the of discussion. For instance, from the findings some of the practices were perceived more by the untrained farmers than the trained farmers as indicated in the responses on weeding, correct spacing, raising of stores, use of wooden pallets, maize condition checks and application of insecticide after shelling.

RECOMMENDATION

It is therefore recommended for annual farm training and evaluation not only in Nandi County but across all maize farming zones in the world to help maintain consistence in GAPs application and minimize the levels of aflatoxin contamination in maize farming zones. Given that contamination can be introduced before and after harvesting, we recommend that training occur during planting, harvesting, and post-harvesting periods.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

ACKNOWLEDGEMENT

The authors would like to thank maize farmers from Nandi County for willingly providing information for use in this study. They also thank the field facilitators and village administrators in every study sub-region, without which the work may not have been possible. Also, credit goes to the research assistants who assisted in data collection and to Angela Andersen for editorial assistance from the Life Science Editors Foundation, Justice Equity Diversity Inclusion (JEDI) awarded to D.N.K. Above all, we appreciate Safe Food, Safe Dairy project for funding the field work.

REFERENCES

Blandino, M., Reyneri, A., & Vanara, F. (2008). Effect of plant density on toxigenic fungal infection and mycotoxin contamination of maize kernels. *Field Crops Research*, *106*(3), 234–241. https://doi.org/10.1016/j.fcr.2007.12.004

Bruns, H. A. (2003). Controlling Aflatoxin and Fumonisin in Maize by Crop Management. *Journal of Toxicology: Toxin Reviews*, *22*(2–3), 153–173. https://doi.org/10.1081/TXR-120024090

Bryceson and Howe. (1992). *Agriculture food and nutrition for Africa—A resource book for teachers of agriculture*. https://www.fao.org/4/w0078e/w0078e07.htm

CAST. (2019). *Council for agricultural science and technology interpretive summary mycotoxins: Risks in plant, animal, and human systems.* (Issue January).

Connor, J. T., & Imrey, P. B. (2014). Proportions: Inferences and Comparisons. In N. Balakrishnan (Ed.), *Methods and Applications of Statistics in Clinical Trials* (1st ed., pp. 570–594). Wiley. https://doi.org/10.1002/9781118596333.ch34

Daniel, W. W. (1999). *Biostatistics: A Foundation for Analysis in the Health Sciences*. Wiley.

Daniel, W. W. (2009). *Biostatistics: Basic Concepts and Methodology for the Health Sciences (Wiley Series in Probability and Statistics) 9th International st edition by Daniel, Wayne W. (2009) Paperback* (9th International edition). John Wiley & Sons Ltd.

Demissie, N. (2018). A Review of Aflatoxin: Occurrence, Prevention, and Gaps in Both Food and Feed Safety. *Novel Techniques in Nutrition & Food Science*, *1*(3), 51–60. https://doi.org/10.31031/ntnf.2018.01.000511

Diener, U. L., Cole, R. J., Sanders, T. H., Payne, G. A., Lee, L. S., & Klich, M. A. (1987). Epidemiology of Aflatoxin Formation by Aspergillus Flavus*. *Annual Review of Phytopathology*, *25*(1), 249–270. https://doi.org/10.1146/annurev.py.25.090187.001341

EAS. (2011). *EAST AFRICAN STANDARD: Maize grains—Specification*. https://law.resource.org/pub/eac/ibr/eas.2.2011.html

Ezekiel, C., Ortega-Beltran, A., & Bandyopadhyay, R. (2019). The need for integrated approaches to address food safety risk: The case of mycotoxins in Africa. *First FAO/WHO/AU International Food Safety Conference. 12-13 Feb, Addis Ababa, Ethiopia*, *Paca*, 2016–2018.

Fandohan, P., Ahouansou, R., Houssou, P., Hell, K., Marasas, W. F. O., & Wingfield, M. J. (2006). Impact of mechanical shelling and dehulling on *Fusarium* infection and fumonisin contamination in maize. *Food Additives and Contaminants*, *23*(4), 415–421. https://doi.org/10.1080/02652030500442516

Fandohan, P., Zoumenou, D., Hounhouigan, D. J., Marasas, W. F. O., Wingfield, M. J., & Hell, K. (2005). Fate of aflatoxins and fumonisins during the processing of maize into food products in Benin. *International Journal of Food Microbiology*, *98*(3), 249–259. https://doi.org/10.1016/j.ijfoodmicro.2004.07.007

FAO. (2019). *World Food and Agriculture—Statistical Pocketbook 2019*.

Finckh, M. R. (2008). Integration of breeding and technology into diversification strategies for disease control in modern agriculture. In D. B. Collinge, L. Munk, & B. M. Cooke (Eds.), *Sustainable disease management in a European context* (pp. 399–409). Springer Netherlands. https://doi.org/10.1007/978-1-4020-8780-6_19

Hawkins, L. K., Windham, G. L., & Williams, W. P. (2005). Effect of different postharvest drying temperatures on Aspergillus flavus survival and aflatoxin content in five maize hybrids. *Journal of Food Protection*, *68*(7), 1521–1524. https://doi.org/10.4315/0362-028X-68.7.1521

Heathcote, J. G., Hibbert, J. R., & Heathcote, J. G. (1978). *Aflatoxins: Chemical and biological aspects*. Elsevier Scientific Publ.

Hell, K., Cardwell, K. F., Setamou, M., & Poehling, H. M. (2000). The influence of storage practices on aflatoxin contamination in maize in four agroecological zones of Benin, West Africa. *Journal of Stored Products Research*, *36*(4), 365–382. https://doi.org/10.1016/S0022-474X(99)00056-9

Hell, K., Cardwell, K., Setamou, M., & Schulthess, F. (2000). Influence of insect infestation on aflatoxin contamination of stored maize in four agroecological regions in Benin. *African Entomology*, *8*, 169–177.

Kang'Ethe, E. K., Korhonen, H., Marimba, K. A., Nduhiu, G., Mungatu, J. K., Okoth, S. A., Joutsjoki, V., Wamae, L. W., & Shalo, P. (2017). Management and mitigation of health risks associated with the occurrence of mycotoxins along the maize value chain in two counties in Kenya. *Food Quality and Safety*, *1*(4), 268–274. https://doi.org/10.1093/fqsafe/fyx025

Kebede, H., Abbas, H. K., Fisher, D. K., & Bellaloui, N. (2012). Relationship between aflatoxin contamination and physiological responses of corn plants under drought and heat stress. *Toxins*, *4*(11), 1385–1403. https://doi.org/10.3390/toxins4111385

KEBS. (2018). *Kenya Bureau of Standards – Standards for Quality Life*. https://www.kebs.org/

Koskei, P. K. (2022). *Post-Harvest Knowledge, Perceptions and Practices by Farmers and Diversity of Fusarium Species and Fumonisin Contamination of Maize from Rift Valley and Lower Eastern Regions of Kenya* [Thesis]. http://repository.kemri.go.ke:8080/xmlui/handle/123456789/477

Lachenbruch, P. A., Lwanga, S. K., & Lemeshow, S. (1991). Sample Size Determination in Health Studies: A Practical Manual. *Journal of the American Statistical Association*, *86*(416), 1149. https://doi.org/10.2307/2290547

Liebman, M., & Dyck, E. (1993). Crop rotation and intercropping strategies for weed management. *Ecological Applications*, *3*(1), 92–122. https://doi.org/10.2307/1941795

Liu, Z., Zhang, G., Zhang, Y., Jin, Q., Zhao, J., & Li, J. (2016). Factors controlling mycotoxin contamination in maize and food in the Hebei province, China. *Agronomy for Sustainable Development*, *36*(2). https://doi.org/10.1007/s13593-016-0374-x

Logrieco, A., Battilani, P., Leggieri, M. C., Jiang, Y., Haesaert, G., Lanubile, A., Mahuku, G., Mesterhazy, A., Ortega-Beltran, A., Pasti, M., Smeu, I., Torres, A., Xu, J., & Munkvold, G. (2021). Perspectives on global mycotoxin issues and management from the mycokey maize working group. *Plant Disease*, *105*(3), 525–537. https://doi.org/10.1094/PDIS-06-20-1322-FE

Magnussen, A., & Parsi, M. A. (2013). Aflatoxins, hepatocellular carcinoma and public health. *World Journal of Gastroenterology*, *19*(10), 1508–1512. https://doi.org/10.3748/wjg.v19.i10.1508

Manu, N., Opit, G. P., Osekre, E. A., Arthur, F. H., Mbata, G., Armstrong, P., Danso, J. K., McNeill, S. G., & Campbell, J. F. (2019a). Moisture content, insect pest infestation and mycotoxin levels of maize in markets in the northern region of Ghana. *Journal of Stored Products Research*, *80*(March), 10–20. https://doi.org/10.1016/j.jspr.2018.10.007

Manu, N., Opit, G. P., Osekre, E. A., Arthur, F. H., Mbata, G., Armstrong, P., Danso, J. K., McNeill, S. G., & Campbell, J. F. (2019b). Moisture content, insect pest infestation and mycotoxin levels of maize in markets in the northern region of Ghana. *Journal of Stored Products Research*, *80*, 10–20. https://doi.org/10.1016/j.jspr.2018.10.007

Marete, G., Kanja, L., Mbaria, J., Okumu, M., Ateku, P., Korhonen, H., & Joutsjoki, V. (2019). Effects of the Use of Good Agricultural Practices on Aflatoxin Levels in Maize Grown in Nandi County, Kenya. *Sci*, *1*(1), 28. https://doi.org/10.3390/sci1010028

Massomo, S. M. S. (2020). Aspergillus flavus and aflatoxin contamination in the maize value chain and what needs to be done in Tanzania. *Scientific African*, *10*(October), e00606. https://doi.org/10.1016/j.sciaf.2020.e00606

Mbugua, S. K., & Gathumbi, J. K. (2004a). The contamination of Kenyan lager beers with Fusarium mycotoxins. *Journal of the Institute of Brewing*, *110*(3), 227–229. https://doi.org/10.1002/j.2050-0416.2004.tb00207.x

Mbugua, S. K., & Gathumbi, J. K. (2004b). The Contamination of Kenyan Lager Beers with Fusarium Mycotoxins. *Journal of the Institute of Brewing*, *110*(3), 227–229. https://doi.org/10.1002/j.2050-0416.2004.tb00207.x

Munkvold, G. P. (2003). Cultural and Genetic Approaches to Managing Mycotoxins in Maize. *Annual Review of Phytopathology*, *41*(May), 99–116. https://doi.org/10.1146/annurev.phyto.41.052002.095510

Muthomi, J. W., Njenga, L. N., Gathumbi, J. K., & Chemining, G. N. (2009). The Occurrence of Aflatoxins in Maize and Distribution of Mycotoxin-Producing Fungi in Eastern Kenya. *Plant Pathology Journal*, *8*(3), 113–119. https://doi.org/10.3923/ppj.2009.113.119

Mutiga, S. K., Mushongi, A. A., & Kangéthe, E. K. (2019). Enhancing food safety through adoption of long-term technical advisory, financial, and storage support services in maize growing areas of East Africa. *Sustainability (Switzerland)*, *11*(10). https://doi.org/10.3390/su11102827

Mutiga, S. K., Were, V., Hoffmann, V., Harvey, J. W., Milgroom, M. G., & Nelson, R. J. (2014). Extent and Drivers of Mycotoxin Contamination: Inferences from a Survey of Kenyan Maize Mills. *Phytopathology®*, *104*(11), 1221–1231. https://doi.org/10.1094/PHYTO-01-14-0006-R

Nkwe, D. O., Taylor, J. E., & Siame, B. A. (2005a). Fungi, aflatoxins, fumonisin B1 and zearalenone contaminating sorghum-based traditional malt, wort and beer in Botswana. *Mycopathologia*, *160*(2), 177–186. https://doi.org/10.1007/s11046-005-6867-9

Nkwe, D. O., Taylor, J. E., & Siame, B. A. (2005b). Fungi, Aflatoxins, Fumonisin Bl and Zearalenone Contaminating Sorghum-based Traditional Malt, Wort and Beer in Botswana. *Mycopathologia*, *160*(2), 177–186. https://doi.org/10.1007/s11046-005-6867-9

Okioma, M. N. (2008). The 2004 and 2005 aflatoxin tragedies in Kenya—A case study. *Mycotoxins: Detection Methods, Management, Public Health and Agricultural Trade*, 127–131. https://doi.org/10.1079/9781845930820.0127

Omara, O., Timothy. (2021). *The Scourge of Aflatoxins in Kenya: A 60-Year Review (1960 to 2020)—Omara—2021—Journal of Food Quality—Wiley Online Library*. https://onlinelibrary.wiley.com/doi/full/10.1155/2021/8899839

Omara, T., Kiprop, A. K., Wangila, P., Wacoo, A. P., Kagoya, S., Nteziyaremye, P., Peter Odero, M., Kiwanuka Nakiguli, C., & Baker Obakiro, S. (2021). The Scourge of Aflatoxins in Kenya: A 60-Year Review (1960 to 2020). *Journal of Food Quality*, *2021*, 1–31. https://doi.org/10.1155/2021/8899839

Probst, C., Njapau, H., & Cotty, P. J. (2007). Outbreak of an Acute Aflatoxicosis in Kenya in 2004: Identification of the Causal Agent. *Applied and Environmental Microbiology*, *73*(8), 2762–2764. https://doi.org/10.1128/AEM.02370-06

Sauro, J., & Lewis, J. R. (2012). *Quantifying the User Experience: Practical Statistics for User Research* (1st edition). Morgan Kaufmann.

Shephard, G. S., Van Der Westhuizen, L., Gatyeni, P. M., Somdyala, N. I. M., Burger, H.-M., & Marasas, W. F. O. (2005). Fumonisin Mycotoxins in Traditional Xhosa Maize Beer in

South Africa. *Journal of Agricultural and Food Chemistry*, *53*(24), 9634–9637. https://doi.org/10.1021/jf0516080

Sumner, P., & Lee, D. (2017). Reducing aflatoxin in corn during harvest and storage. *UGA Cooperative Extension Bulletin 1231*, 6 pp.

Turner, P. C., Sylla, A., Gong, Y. Y., Diallo, M. S., Sutcliffe, A. E., Hall, A. J., & Wild, C. P. (2005). Reduction in exposure to carcinogenic aflatoxins by postharvest intervention measures in west Africa: A community-based intervention study. *Lancet*, *365*(9475), 1950–1956. https://doi.org/10.1016/S0140-6736(05)66661-5

Udoh, J. M., Cardwell, K. F., & Ikotun, T. (2000). Storage structures and aflatoxin content of maize in five agroecological zones of Nigeria. *Journal of Stored Products Research*, *36*(2), 187–201. https://doi.org/10.1016/S0022-474X(99)00042-9

Wagacha, J. M., & Muthomi, J. W. (2008). Mycotoxin problem in Africa: Current status, implications to food safety and health and possible management strategies. *International Journal of Food Microbiology*, *124*(1), 1–12. https://doi.org/10.1016/j.ijfoodmicro.2008.01.008

Winfred, M. K., Joshua, O. O., Jackson, N. O., & Peter, B. G. (2022). Knowledge of subsistence maize farmers on aflatoxin contamination and determinants for adoption of artisanal control technologies in Kitui, Kenya. *Journal of Agricultural Extension and Rural Development*, *14*(4), 198–209. https://doi.org/10.5897/jaerd2022.1348

Yau. (2018). *Aflatoxins in Food*. Food Safety Focus. https://www.cfs.gov.hk/english/multimedia/multimedia_pub/multimedia_pub_fsf_73_02.html

Zummo, N. (1992). Interaction of Fusarium moniliforme and Aspergillus flavus on Kernel Infection and Aflatoxin Contamination in Maize Ears. *Plant Disease*, *76*(8), 771. https://doi.org/10.1094/pd-76-0771