**Participatory Evaluation of Pre-harvest Aflatoxin Control Practices in Eastern Province of Zambia**

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**ABSTRACT**

Aflatoxins contamination remains a major challenge for small holder groundnut producers in Eastern Zambia. The stringent regulatory regimes in lucrative international markets continue to deny market access by groundnuts produced in this region. The research activity was carried out in Eastern Province of Zambia, with the objective of evaluating and demonstrate pre-harvest technologies to groundnut farmers. On-farm trials were carried at Chinkhombe and Kalichero Agricultural Camps, while an on-station trial was carried at Mount Makulu Central Research Station from 2015-2017. During the period, regular visits, trainings, field days and village meetings were conducted with farmers to enhance researcher – farmer interaction. In both on-farm and on-station trials, significantly high levels of low levels aflatoxin were observed in groundnuts planted in tied ridges. However, while on-farm trials had low levels of aflatoxin in 2017 this was not case for on-station as it was planted late and experienced end-season dry spells. Beside aflatoxin assessment, farmers provided a feedback on their experiences with different treatments during village meetings thus enabling researchers to plan and develop farmer preferred technologies. It’s evident that sustainable lower levels of aflatoxins would be achieved if farmers used good agronomic practices and were well informed.

**Key words**: Aflatoxin; awareness, groundnuts, on-farm, pre-harvest

**INTRODUCTION**

Groundnut (*Arachis hypogaea* L.) is one of the dominant food and cash crops in Zambia that enable most of smallholder farmers earn a livelihood (Ross et al., 2012). The main groundnut producing areas are Eastern (31%), Central (17.2%) Southern (13.7%) and Northern provinces (9.2%) (CSO, 2016). Despite the importance of the crop among smallholder farmers in the country, its production and productivity countrywide has continued to decline due to the occurrence of high levels of aflatoxins. Aflatoxins are a group of structurally related toxic polyketide-derived secondary metabolites produced by certain strains of *Aspergillus flavus* and *Aspergillus parasiticus* (CAST, 2003). They pose serious health concerns and limits the crops market potential in accessing the lucrative European, American and Middle-East markets (Ross and Klerk, 2012; Matumba et al., 2015) Pre- and post-harvest infection by *Aspergillus* spp. and the environmental factors that lead to aflatoxin accumulation in vulnerable crops like maize and groundnuts have been reviewed in detail (Walifyar et 2015; Bandyopadhyay et al., 2016; Villers, 2016).

Aflatoxin contamination of groundnut may occur before harvest while the crop is maturing in the field particularly favored by drought stress, heat and high soil temperature and may continue to proliferate in storage under conducive environmental conditions. Thus with these favourable conditions, Aflatoxin contamination may occur in the kernels and on pods in the soil a few days or weeks before harvest, at harvest, and in storage during post-harvest handling (Cotty and Mellon, 2006). While the management of aflatoxin contamination in groundnuts is complex, some cultural practices, such as: pre-season ploughing, early planting to escape periods of mid-season and end season drought that might occur, use of biocontrol agents, maintaining good plant density in the fields, removal of premature dead plants, managing both field and storage insect pests and diseases, timely harvesting, exclusion of damaged and immature pods, quick pod drying, and storing the pod/seed with less than 10% moisture content have been identified to be effective in preventing fungal infection and proliferation (Bandyopadhyay et al., 2016; Walifyar et 2015). In Zambia, several of these agronomic have been promoted for adoption by small-scale farmers (ZARI, 2015). However, most of these pre-harvest management options though cost-effective and practical under subsistence or small-scale farming conditions, remain largely un-adopted by farmers. Consequently, the levels of aflatoxins along the groundnut value chain has continued to be high (Ngoroge et al., 2016).

Therefore, this study was undertaken to evaluate, demonstrate and validate pre-harvest aflatoxin technologies/practices that had been popularized by research and extension over 10 years in Zambia so has to enhance their adoption and also re-affirm their efficacy in aflatoxin management.

**METHODOLOGY**

1. *Field trials*

*On-farm evaluation trials*

On-farm trials were conducted in Eastern Province in two agricultural camps, Kalichero and Masamba in Chipata and Katete districts, respectively during 2015/16 and 2016/17 seasons (Figure 1). Eastern province lies in the mid-rainfall agro-ecological region II of Zambia, characterized by a unimodal rainfall distribution between 800-1000mm, a crop growing season of 120-150 days long, and an average temperature of 16-25oC. Eastern province is highly suited for groundnuts cultivation due to high rainfall as well as coarse textured and sandy loam soils. According to CSO (2016), there were 308,119 groundnut households in the province, of which 53.2% were actively involved in groundnut production and in 2013/14 season they produced 54000 MT.

The two agricultural camps were purposively because of their high importance in groundnut production in their respective districts, accounting for slight above 15% of the area under groundnut production, and also being serviced by Farmer out grower foundation limited, one of the project partners. The environmental characteristics of the sites are presented in Table 1. Before commencement of on-farm trials, pre-season meetings/trainings were held with the farmers, village headmen and extension staff to discuss the project’s aims and objectives. Strategies for input (seed and fertilizer) distribution were developed. In each agricultural camp, the farmers were organized into a group with a group leader who was contact point between the farmers and the research team.

Eighty (80) smallholder farmers who attended inception meetings in December 2015, an equal number of farmers in Kalichero and Chinkhombe agreed to participate in the project activities. It was observed that farmers presented had at least planted their groundnuts using one of the four planting methods: single row, double row, tie-ridges and flat field, which were eventually agreed to as the pre-harvest planting methods to be evaluated and demonstrated for their efficacy against aflatoxins accumulation in matured groundnuts. Planting on flats i.e. no ridges was chosen as control. Since planting for 2015/16 season had already been done the number of farmers were not equally among these planting methods.



Figure 1 Map of Eastern Province of Zambia (Source: http:www.google.co.zm/map of Eastern Province html.2017)

In 2016/17, fourteen lead farmers (each with 10 -15 follower farmers according to farmer registrar and village headmen) participated in the trials. With few numbers of participating farmers, it was possible to ensure uniformity in the size of fields used for the trials, besides hosting of the field days. Each of the participating farmer set aside 0.2ha of their farmland for the trials. This area was then sub-divided into two equal plots, 100m2 each. Groundnuts were planted according one of the two methods, each farmer used. This enabled the farmer to compare at least two planting methods. In both seasons, farmers planted MGV-4, a popular groundnut variety in Zambia, during the first week of December. The crop was grown and managed by farmers, with minimal supervision by FOF staff and the research group that comprised a multidisciplinary team of an agronomist, plant breeder, an entomologist and a statistician. At harvest, 5kg-unshelled groundnut sample was collected from each of the participating farmers for aflatoxin analysis. In addition, a matrix ranking was used to assess farmers’s opinion and perceptions on the attributes of the different planting methods/technologies.

**Table 1.** Testing sites description for two seasons (2015–2017)

|  |  |  |  |
| --- | --- | --- | --- |
| Environmental factor |  | Sites |  |
|  | Kalichero  | Chinkhombe  | Mount Makulu |
| Latitude (S) | S 13o26 60',  | 14o1'60,  | 15o32.87’ |
| Longitude (E) | E 32o21'1 | 31o55'60 | 28o14.92’ |
| Altitude (m asl) | 1040 | 1069 | 1206 |
|  |  |  |  |
| Year | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 |
| Annual rainfall (mm) | 758 | 1244 | 432.9 | 707.9 | 687.8 | 958.3 |
| Max. temperature (o C) | 28 | 27.5 | 26.7 | 28.1 | 14 | 15 |
| Min. temperature (o C) | 16.1 | 16.8 | 15.8 | 14 | 24 | 23 |

Note: m asl=metres above sea level

*On-station field trials*

Field trial was set up at Mount Makulu Central Research Station, Chilanga (also in AEZ II) in December 2015 and January 2017. The delayed planting during 2016/17 season was result of poor seed initially sourced that failed to germinate and the trial had to be replanted towards the end of January 2017, with rains ending in first week of April, it was exposed to intermittent water supply until the crop matured. The environmental characteristics of Mount Makulu are presented in Table 1. The four planting methods were double row, single row, tie-ridges and the control- flats (no ridges). The planting was done in a randomized complete block design with four replications with each plot size measuring 4 x 5m2. The test crop was Groundnut variety MGV-4 planted at a spacing of 0.75 x 0.15m. Standard crop management practices were applied. At harvest 5-kg unshelled groundnut from each plot was set aside for aflatoxin analysis. Aflatoxin content from both on-farm and on-station trials were analysed by a single –step lateral flow immunochromatographic assay, Reveal Q+ for Aflatoxin (Neogen Food Safety, Lansing, MI) following standard procedure at Msekera Aflatoxin Laboratory. Aﬂatoxin content were measured in micrograms per kilogram (µg per kg or ppb).

 *(b) Data analysis*

Aflatoxin values were transformed using the transformation (Log10 [aflatoxin +10] to improve normality and constant variance and back-transformed. Means were compared using paired t-test and multiple comparisons were done using analysis of variance general linear models and Least Significant Differences (LSD) in Genstat v. 13.3 (VSNi, 2010).

**RESULTS AND DISCUSSION**

*On-farm trials*

On-farm trials revealed high significant aflatoxin difference between the years (P=0.002) and among treatments (p=0.05) (Figure 2) with higher amounts of aflatoxins recorded in 2017 (34 ppb). Among treatments, the groundnuts planted on flats had highest aflatoxin contamination (44.2ppb), followed by those planted in double rows (33.2ppb). The lowest was in tied ridges (7.4ppb).

The summary of key observations by the participating farmers are presented in Table 2. Though the data was not gender desegregated and was done only in 2017, most of participating farmers indicated that double rows produced more pods, but smaller. They reported that this planting method had a high presence of pod rot (black pods) at harvest. In general, they found four planting methods were ease to implement though making tie-ridging required a slight more extra labour. The one major advantage with tie-ridging was that plants were less prone to dry spell or drought stress; they did observe any plants wilting.

**Figure 2** Levels of aflatoxins in groundnuts collected from farmers that used different pre-harvest aflatoxin management methods

**Table 2**. Summary of key field observations by farmers in two agricultural camps

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Camps | Double row |  Flats | Single row | Tie-ridging |
| Kalichero | -Less weeds-Smaller pods-Presence of black pods (pod rot)-Gives good harvest | -Too weedy-Ease to plant-Difficult for field operation during rains | -Bigger pods-Less moldy pods-Raised ridges limits water logging | -Plants don’t wilt during dry spells-Extra labour cost for field preparation |
| Chinkhombe  | -Less weeds-Smaller pods-More pod yield-Incidence of pod rot high | -Poor plant stand-Too weedy-Ease to plant-Difficult to dig out pods | -Bigger pods- Low incidence of pod rot  | -Bigger pods-Plants don’t wilt during dry spells-Extra hands for preparation-Difficult to establish in stony fields |

***Researcher-managed fields***

There were significant differences between the years (P=0.016) and among the treatments (P=0.047; log transformed data) (Figure 2). The highest levels of aflatoxin concentration were recorded in 2017 (166 ppb). This was five more than observed in 2016 (36 ppb). Among the treatments, significantly higher levels of aflatoxins were in the groundnuts grown in double rows (309 ppb) in 2017, followed by control - flat field (172 ppb) and the least was in Tied ridges (57 ppb) though the latter was not statistically different (P> 0.05) from Single rows.

In 2016, the lowest levels were in Tied ridges (12ppb) while in 2017 it was in Tied ridges (4ppb)

Figure 2. Aflatoxin levels in the different agronomic management options at Mount Makulu Research Station, Chilanga

The results further revealed that significant differences only existed between planting on tied ridges and other treatments (Table 3).

**Table 3.** Comparison of the various treatment across three sites

|  |
| --- |
| **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 | DR – FF | 17.31765 | 151.74311 | 26.02373 | -35.62803 | 70.26332 | .665 | 33 | .510 |
| Pair 2 | DR – SR | 35.61176 | 119.37036 | 20.47185 | -6.03852 | 77.26205 | 1.740 | 33 | .091 |
| Pair 3 | DR – TR | 61.11882 | 143.18933 | 24.55677 | 11.15770 | 111.07994 | 2.489 | 33 | .018\* |
| Pair 4 | FF – SR | 18.29412 | 81.08349 | 13.90570 | -9.99725 | 46.58548 | 1.316 | 33 | .197 |
| Pair 5 | FF – TR | 45.89257 | 63.90849 | 10.80251 | 23.93924 | 67.84591 | 4.248 | 34 | .000\*\* |
| Pair 6 | SR – TR | 25.50706 | 51.23677 | 8.78703 | 7.62971 | 43.38441 | 2.903 | 33 | .007\*\* |

Note: \*, \*\* indicate significance at P=0.05 and P=0.01 respectively

DR=Double row, FF=Flats (no ridges-control); SR=Single row; TR=Tied ridges

|  |
| --- |
|  |

On average there was 82% reduction when tied ridges were used compared to the control treatment – planting on flats (Table 4). To the contrary, planting in double rows resulted in 25% increase in aflatoxins more than the control. The rank order of the treatment was similar at all three sites though Mount Makulu experienced more aflatoxin contamination than the other two sites, maybe this a reflection of late planting of the trial in spite of the good rains witnessed in 2016/17 in most parts of the country.

**Table 4.** Percent reduction in aflatoxins (%)of the methods at the three sites over the years

|  |  |  |  |
| --- | --- | --- | --- |
| Method  |  | Sites |  |
|  | Chinkhombe | Kalichero | Mount Makulu |
| Double rows | -29.7 | (29.5) | 10.7 | (39.3) | 41.5 | (130.4) |
| Flats | 0.0 | (41.9) | 0.0 | (35.4) | 0.0 | (92.2) |
| Single row | -48.7 | (21.5) | -38.3 | (21.6) | -39.5 | (55.8) |
| Tied ridges | -74.5 | (10.7) | -92.2 | (2.3) | -72.4 | (25.4) |

*Note: Figures in the parentheses are the means at each site*

While the average aflatoxin figures obtained at these sites except for tied ridges at Kalichero may be higher than the allowable limits in both Zambia and EU, which is the potential market, the observed reduction in aflatoxin would be the first step in producing better quality groundnuts. Sorting and grading and other post-harvest methods would then argument this process and ensure further reduction in levels of aflatoxins (Walifyar et al, 2014). The better performance of tied ridges re-affirms the understanding that by allowing high soil moisture retention in inter-row “ponds” this may result in lower aflatoxin build-up in maturing pods. It’s also clear from the results that in years, where an area experiences mid-season dry spells or end-season drought during the cropping season there would no significant difference between planting on flats and using tied ridges. The opposite is also true in presence of water pools on flats during above rainy season.

**CONCLUSIONS**

Participatory evaluation trials such as these have provided both farmers and researchers firsthand information on the performance of different planting methods (treatments) in reducing aflatoxins in groundnuts under varying farmer conditions. Apart from tied ridging that produced very low permissible aflatoxins at least in one site, it’s possible to use a combination of methods together with post-harvest technologies to achieve the allowable limits of aflatoxins in groundnuts. The importance and complex nature of aflatoxin research demands coordinated effort among all actors in the value chain in order to ensure that appropriate technologies are developed and promoted. Once the benefits of these technologies are noticed by farmers, they would stimulate a process of auto-diffusion through a self-motivated farmer to farmer horizontal spread of information. This would inevitably lead to increased adoption rates, increased crop productivity and production of a healthier crop for consumers and producers alike.

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