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Research Application Summary

Reducing pre-harvest aflatoxin content in groundnuts through soil water management

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Abstract

In Zambia, groundnut (*Arachis hypogaea* L.) is an important food and market crop. However, the crop has very limited access to international markets due to high concentrations of aflatoxins in kernels, which pose serious health concerns. There exists several promising field intervention measures to minimize pre-harvest aflatoxin incidence. Good agricultural practices that contribute to prudent management of soil moisture have shown potential to reduce aflatoxin incidence. In this study, we investigated the effect of three soil moisture management practices on pre-harvest aflatoxin content in groundnuts. Treatments included controlled irrigation during pod-development, time of planting within a growing season, and application of manure. Soil from experimental sites was sampled from the top 20 cm and characterized using standard laboratory procedures. In each case, a Virginia bunch type groundnut variety was planted and grown to full maturity. The harvested pods were sampled, dried to about 8 % moisture content, shelled and then tested for aflatoxin content using the Reveal Q+ Aflatoxin Testing Kit. To determine the distribution of means, the data collected were subjected to either the Analysis of Variance or the alternative Kruskal Wallis Test at 95 % Confidence Interval. Results indicated up to 10-fold reduction in aflatoxin content with increasing soil moisture status during pod development. Therefore, it can be concluded that maintaining a favorable soil moisture status is a key factor in minimizing pre-harvest aflatoxin risk in groundnuts.

Key words: Aflatoxins*, Arachis hypogaea,* soil moisture, Zambia

Résumé

En Zambie, l'arachide (*Arachis hypogaea L.*) est un important aliment et culture de marché. Cependant, la culture a un accès très limité aux marchés internationaux en raison de fortes concentrations d'aflatoxines dans les grains, qui posent des problèmes graves de santé. Il existe plusieurs mesures d'intervention prometteuse sur le terrain pour réduire au minimum, avant la récolte, l'incidence d'aflatoxine. Les bonnes pratiques agricoles qui contribuent à une gestion prudente de l'humidité du sol ont montré le potentiel de la réduction de l'incidence de l'aflatoxine. Dans cette étude, nous avons réalisé l'effet de trois gestions pratiques de l'humidité des sols sur la teneur en aflatoxine dans les arachides, avant la récolte. Les traitements comprenaient l'irrigation contrôlée pendant le développement de cosse, le moment de la plantation dans une saison de croissance, et l'application de fumier. Le sol des sites expérimentaux a été échantillonné à partir des 20 premiers cm et caractérisé en utilisant des procédures standard de laboratoire. Dans chaque cas, un type de bouquet de variété d'arachide Virginia a été planté et cultivé à pleine maturité. Les gousses récoltées ont été échantillonnés, séché à environ 8% d'humidité, décortiquées et ensuite testés pour la teneur en aflatoxine utilisant le Relevé Q + Kit de Test d'aflatoxine. Pour déterminer la répartition des moyens, les données recueillies ont été soumis soit à l'analyse de la variance ou l'alternative du Test de Kruskal Wallis à 95% Intervalle de confiance. Les résultats ont montré jusqu'à 10 plis réduction de la teneur en aflatoxine avec l'augmentation de l'état de l'humidité du sol au cours du développement des gousses. Par conséquent, on peut conclure que le maintien d'un état d'humidité du sol favorable est un facteur clé dans la réduction du risque de l'aflatoxine avant la récolte des arachides.

Mots clés: Aflatoxines, *Arachis hypogaea*, humidité du sol, la Zambie

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Background

Groundnut (*Arachis hypogaea* L.) is an important food and cash crop of Zambia (Sitko *et al*., 2011). However, the occurrence of high concentrations of aflatoxins poses health concerns and limits the crops market potential (Derlagen and Phiri, 2012; Ross and Klerk, 2012). Aflatoxins can be defined as invisible poisonous chemical compounds produced by toxigenic species of *Aspergillus*, predominantly *Aspergillus flavus* and *Aspergillus parasiticus*. In spite of the ubiquitous nature of *Aspergillus*, the occurrence of aflatoxin contamination is mostly associated with warm and dry climates (CAST, 2003).

Agricultural practices that counter the effects of drought by keeping the soil moist and cool during pod development have potential to minimise pre-harvest aflatoxin risk. In this study, we explored three soil water management practices that have been linked to reduced fungal infestation of developing groundnut pods and subsequent aflatoxin development in kernels. These measures included, maintaining a high soil organic matter content, timely planting and controlled irrigation.

Materials and methods

Study sites representing major groundnut-producing regions of Zambia were selected to test promising pre-harvest aflatoxin mitigation measures. The sites were; Kasisi Agricultural Training Centre (15°14'58.5" S and 28°29'00.6" E) for the effect of soil organic matter, a greenhouse at the University of Zambia, Great East Road Campus (15°23.642'S and 28°28.057'E) for the effect of controlled irrigation during pod- development and Msekera Agricultural Research Station (13°39'10.0" S and 32°33'00.6" E) for the effect of three planting dates. Prior to laying out the experiments soil characterization was done for the soils from the study sites. Composite soil samples from selected sites were collected by random sampling to a depth of 20 cm and then characterized using standard laboratory procedures. The selected soil parameters analysed included texture, bulk density, organic matter, soil reaction (pH), total N, available phosphorus and exchangeable cations.

For the field studies, the following treatments were evaluated in this study: (a) Controlled irrigation: 25, 50, 75 and 100 % of 500 mm crop water requirement from flowering to maturity. (b) Soil organic matter: decomposed chicken manure applied to increase native soil organic matter of 0.71 % to 1, 1.5, 2, 2.5 and 3 %; and (c) Time of planting: Planting with the first effective rains (first 30 mm), 7 days and 14 days after the first planting. In each case, a Virginia bunch type groundnut variety (MGV 4) was planted and grown to full maturity. At full maturity, the crop was harvested and aflatoxin concentrations determined from dried kernels (8 % moisture content). The aflatoxin data were then subjected to Analysis of Variance or the equivalent Kruskal Wallis Test at 0.05 level of significance.

Results and discussion

Effect of soil water content on pre-harvest aflatoxin concentrations. Mean total aflatoxin concentrations ranged from 2.2 ppb to 25.5 ppb with a mean of 19.0 ppb (Table 1). Aflatoxin content reduced with increasing water supply to the crop. It is possible that higher soil moisture availability is likely to enhance the production of phytoalexin and thus minimize fungal infections (Wotton and Strange, 1987). The current study showed that even a minimal water stress from 100 % to 75 % crop water requirement can elevate aflatoxin concentrations up to more than 10-folds. With more severe and rampart droughts being experienced in the tropics since the 1970s (IPCC, 2007), due to climate change, crop exposure to water stress is also becoming rampart and likely to elevate aflatoxin concentrations in kernels. There is therefore need for consented efforts to conserve soil water in order to mitigate the negative effects of water stress. Going by Zambian Standards on aflatoxins in peanut butter (ZS 723: 2008), only the 100 % treatment produced groundnuts that would meet the tolerable limit of 15 ppb total aflatoxin concentration.

Table 1. Aflatoxin contamination as influenced by drought stress during the final six weeks of the growing season[a]

Moisture level	Water supplied during final 42 days of the growth cycle	Mean total aflatoxin concentration in kernels
% crop water requirement	(mm)	(µg/kg)
25	125	25.5 a
50	250	23.9 a
75	375	24.3 a
100	500	2.2 b

[a]Means for aflatoxin contamination followed by the same letter are not significantly different according to Fisher's Protected LSD at $p \leq 0.05$

Effect of soil organic matter content on pre-harvest aflatoxin concentrations. The results in Table 2 show that total aflatoxin concentrations ranged from 1.0 ppb to 9.9 ppb with a mean of 2.9 ppb. There was a 27 % reduction in mean total aflatoxin concentrations with an increase in soil organic matter content. The highest reduction was achieved at 3 % (w/w) rate of manure application which gave mean total aflatoxin concentration of 2.4 ppb. Waliyar *et al*. (2013) reported a 42 % reduction in total aflatoxin content in groundnuts grown with an application of farmyard manure at a rate of 2.5 tons/hectare before planting. However, in the current study, the 3 % manure treatment was equivalent to 16.9 tons/ha applied before planting. Considering such a huge quantity of manure, it implies that this technique can work well in soils with a higher native soil organic matter content. The 2.5 tons/hectare recommendation by Waliyar *et al*. (2013) does not give an indication of the native soil organic matter content. The reduction in aflatoxin content can be attributed to an improved soil water holding capacity, soil fertility status and soil microbial activity at higher soil organic matter contents. Improved soil microbial activity minimizes the dominating tendency of *Aspergillus flavus* under low soil moisture availability and fertility conditions (Pitt *et al*., 2013).

Effect of time of planting in a season on pre-harvest aflatoxin concentrations. From Table 3, mean concentrations of aflatoxin B_1 ranged from 3.8 ppb to 89.0 ppb with a mean of 43.4 ppb. Results revealed a very significant increase in aflatoxin load in kernels of groundnuts planted later in the season. The first planting date corresponded with the first 30 mm rainfall (initial rains that are sufficient to ensure good crop germination and establishment), while the second and third planting dates represent 7 days and 14 days after the first effective rains, respectively. The planting date of a rain-fed crop can affect plant performance due to a number of reasons including moisture availability and soil temperature fluctuations. For most crops, a suitable planting date is one which allows the crop to complete its growth cycle within the rainy season. In groundnuts, exposure to late season drought during pod-formation is likely to increase pre-harvest aflatoxin content in kernels due to moisture stress combined with elevated soil temperatures (Torres *et al*., 2014). In this study, only the first planting date produced kernels with tolerable aflatoxin content for less strict markets such as the US Market with a threshold of 20 ppb total aflatoxins.

Table 2. Aflatoxin contamination as influenced soil organic matter content at time of sowing[a]

Soil organic matter content (% w/w)	Quantity of manure applied (t/ha)	Mean total aflatoxin concentration in kernels (μg/kg)
0.7	0 (control)	3.2 abcde
1	2.2	3.3 bcd
1.5	5.9	3.2 cde
2	9.6	2.6 def
2.5	13.2	2.5 ef
3	16.9	2.4 f

[a]Means for aflatoxin contamination followed by the same letter are not significantly different according to Fisher's Protected LSD at $p \leq 0.05$

Table 3. Aflatoxin contamination as influenced by seeding date in relation to drought stress during the latter part of the growing season[a]

Planting date	Rainfall during final 30 days of the season (cm)	Mean aflatoxin B_1 concentration in kernels (µg/kg)
31st December, 2014	9.9	4:00 a
8th January, 2015	2.73	37 b
15th January, 2015	0	89 c

[a]Means for aflatoxin contamination followed by the same letter are not significantly different according to Fisher's Protected LSD at $p \leq 0.05$

Conclusions

Adequate soil water management especially during pod development in groundnuts can reduce pre-harvest aflatoxin content in kernels. High soil organic matter content helps conserve soil water and thus reduce aflatoxin incidence. Similarly, planting at the on-set of rains can reduce crop exposure to end of season drought and ensure adequate soil moisture levels during pod-formation. These practices can help to meet the crop water requirements of the crop before harvesting. Therefore, ensuring adequate soil moisture and fertility status is key to minimising pre-harvest aflatoxin risk in groundnuts.

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