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Managing aflatoxin in smallholder groundnut production in Southern Africa: Paired comparison of the windrow and Mandela cock techniques

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ABSTRACT

Timely drying of groundnuts is important after harvest. In most parts of sub-Saharan Africa, moisture content reduction is practically achieved by solar drying. In particular, the groundnuts are traditionally cured in the field using the inverted windrow drying technique. Recently, the Mandela cock technique, a ventilated stack of groundnut plants with a chimney at the center, has been introduced in the southern Africa region with the aim of reducing moisture content and the risk of aflatoxin contamination. An on-farm study was conducted in Malawi to compare the effectiveness of the Mandela cock and Windrow drying techniques with respect to aflatoxin control. For two consecutive years, farmers (2016, n = 29; 2017; n = 26) were recruited to test each of the two drying techniques. A mixed-design ANOVA showed that the Mandela cock groundnut drying technique led to significantly ($p < 0.001$) higher aflatoxin levels in groundnut seed compared to the traditional inverted windrow drying (5.7 μg/kg, geometric mean vs 2.5 μg/kg in 2016 and 37.6 μg/kg vs 8.4 μg/kg in 2017). The present findings clearly demonstrate the need for regulation and technology validation if farmers and consumers are to benefit.

1. Introduction

Aflatoxin contamination in groundnut (*Arachis hypogaea*), is a serious problem worldwide affecting human health and restricting trade in affected products. Aflatoxins are secondary metabolites produced mainly by *Aspergillus flavus* and *A. parasiticus* and have been linked to immunosuppressive, hepatotoxic, carcinogenic, mutagenic, and teratogenic effects in laboratory animals (Wong and Hsieh, 1976; Williams et al., 2004; Oswald et al., 2005; El-Nahla et al., 2013), and the same problems could occur in humans. The aflatoxigenic fungi may invade and contaminate the developing groundnut pods with aflatoxin prior to lifting following severe late-season drought stress (Griffin and Garren, 1976; Dorner et al., 1989, 1998; Guo et al., 2009), pod damage by insects (Widstrom, 1979) and over maturity (McDonald, 1970; Mehan et al., 1986; Dorner et al., 1989). However, in the developing world, most aflatoxin contamination occurs at harvest and during drying and subsequent storage (Wild and Hall, 2000; Williams et al., 2004; Turner et al., 2005). Aflatoxin in groundnuts leads to reduced crop yields as contaminated seed has to be discarded and farmers receive less income from reduced sales.

In developing countries within the tropics, groundnuts are often harvested under humid, warm and rainy conditions. The majority of farmers lack drying equipment (Matumba et al., 2017a) and rely on sun-drying (solar drying), often placing the harvested groundnuts on ground in contact with soil where exposure to contamination is much more likely. The groundnuts are often manually lifted from the soil with the aid of a hand hoe. The groundnut plants (with pods intact) are then windrowed in the field until lower storage moisture levels are achieved. A windrow is a long low ridge or line of harvested crop plants, designed to achieve the best conditions for drying. The two types of windrow can

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be described as follows: 1) a random windrow where plants are left to dry haphazardly with most of the pods covered by foliage; and, 2) an inverted windrow where the plants are inverted to expose the pods to sunlight (Porter and Garren, 1970) (Fig. 1).

Drying of groundnuts using the inverted windrow technique was found to be more rapid and less favourable for mould development than random windrows (Porter and Garren, 1970; Porter and Wright, 1971). Subsequently, inverted windrows have been advocated by most extension agents worldwide. Recently, the Mandela cock[1] groundnut drying technique (Fig. 2), which involves windrowing the groundnuts for a few days followed by stacking of the plants, has been introduced in the southern African region and is now in widespread use by small scale groundnut farmers following its dissemination by government and non-government actors. There is limited information regarding the origin of the practice and the name. It appears that the name 'Mandela cock' stems from a *haycock,* which refers to a small cone-shaped pile of hay that has been left in the field until it is dry enough to be carried to the hayrick. The use of a 'cock' to dry groundnut is highlighted in an FAO groundnut publication of a decade and a half ago as one of the traditional groundnut drying techniques employed in Nigeria and certain parts of southern Africa (Nautiyal, 2002). However, the roots of the 'Mandela' prefix are not clear. Perhaps the inclusion of the Mandela name is in recognition of the fact that the practice was developed in South Africa.

According to a recently published groundnut instruction manual, the Mandela cock technique involves windrowing groundnuts for 1–4 days (to rapidly reduce moisture) followed by constructing a circular platform of soil about 1 m in diameter which supports a single layer of inverted plants compressed together filling the whole platform (AICC, 2014). Subsequently, more bunches of groundnut plants are added horizontally (with pods facing inward) on the periphery of the circle leaving a chimney at the center. In each successive layer, the diameter of the chimney is reduced and the pods are arranged towards the center of the stack until a maximum height of about 1.5 m is attained. The chimney is then closed with one or two plants and the stack is left uncovered in the field for about 2–4 weeks depending on humidity, temperature and wind movement. Proponents of the Mandela cock drying technique claim that it reduces the risk of aflatoxin contamination as there is rapid initial moisture reduction from the windrowing step. It is also believed that stacking in a cock prevents rain water ingress, although we were unable to find evidence to support this view.

To address this gap in knowledge the current study was carried out to systematically compare the performance of the two techniques (inverted windrow and Mandela cock technique) with respect to aflatoxin incidence. The primary objective was to establish whether there is a difference in the total level of aflatoxin in groundnuts dried using the two techniques. A further aim was to identify whether aflatoxin levels differed between years and whether any treatment differences were consistent over time. It is expected that the findings of the study will help to reduce yield losses in groundnuts due to rot and aflatoxin accumulation.

2. Materials and methods

2.1. Site selection and recruitment of participant farmers

A total of 29 randomly selected smallholder farmers were recruited from Lilongwe (Mpenu and Mitundu Extension Planning Areas (EPA), 7 farms), Mchinji (Chiosha EPA, 13 farms) and Dowa (Mponera EPA, 9 farms) districts during the 2015/16 growing season (under rain fed conditions). The experiment was repeated during the 2016/17 season in 26 farms in Mikundi EPA in Mchinji district. The site selection for the 2016/17 growing season was based on logistical reasons and the number of participating farms depended on the willingness of the farmers to participate in the study. The multi-locational farmer-managed trials were conducted over two growing seasons in order to take into consideration the variability that could arise from diversity of stack architecture (chimney diameter, stack height, foliage density), groundnut moisture levels, and environmental conditions including field fungal population.

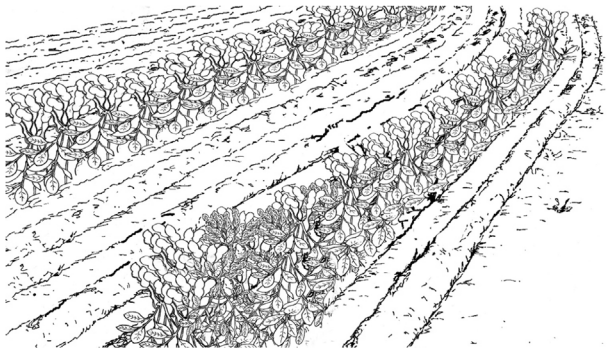

Fig. 1. Inverted windrow.

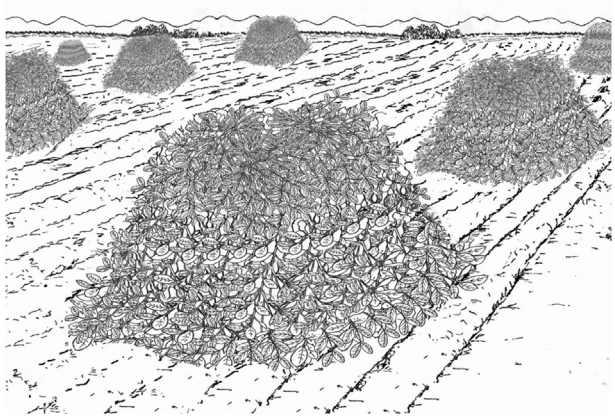

Fig. 2. Mandela cock.

2.2. Groundnut field establishment and crop management

Groundnuts of the cultivar Virginia bunch CG 7 (the most popular variety in Malawi which was released in 1990) were freely distributed to all participating farmers. Seeds were planted by all the farmers with the first planting rains (approximately 20–30 mm). Malawi has one rainfall season that stretches from October/December to April/May. Based on the rainfall pattern, in the 2015/16 growing season, groundnut was planted between 20 and 22 December 2015, while during the 2016/17 growing season, the crop was planted between 27 and 29 November, 2016.

Agronomic practices recommended for Virginia-type groundnuts were used (Ministry of Agriculture, 1993). Soil fungicides and nematicides were not used. Further, no inorganic fertilizers were applied as is the practice in Malawi. All these practices were applied by the farmers themselves with minimal guidance from the extension worker. Plants were harvested between 125 and 140 days after planting. After harvest the groundnuts were dried in the field using two techniques: 1) inverted windrow (hereafter referred to as windrow); and, 2) the Mandela cock technique. This was done under the guidance of an extension worker. The crops were harvested in May in 2016 and April in 2017, respectively, and the cropping seasons are hereafter referred to as '2016' and

[1] A different spelling (Mandela 'cork') exists on the web (African Institute of Corporate Citizenship (AICC), 2014; ICRISAT Open Access Repository, 2012).