Climate change impacts on peanut quality in the sub-tropical Australia

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Abstract

When subjected to high temperature and drought in the field kernels of several food crops including peanuts (*Arachis hypogaea* L.) accumulate the highly carcinogenic aflatoxin, which is produced by invading *Aspergillus flavus* and *A. parasiticus* fungi. The toxigenic potential of these fungi adds another dimension to the imminent challenge to global food security in the face of climate change. Using an aflatoxin risk model for peanuts grown at Kingaroy (-26° 32'S 151° 50'E) in south-east Queensland, Australia, this study highlights how climate change can impact on food safety, in addition to food security. The modelling scenarios covered simulations from 1890 to the present time, and showed a 11.7% decrease in pod yield since 1980. In contrast, the risk of suffering significant aflatoxin contamination, which was 1 in 11 years until 1979, increased to 1 in 3 years thereafter. Climatic analysis of the study area indicated that since 1980, when changes in the risk became more noticeable, in-season crop rainfall decreased by 8%, maximum temperature increased by 2.1% (0.6°C) and minimum temperature by 7.4% (1.1 °C) while radiation remained unchanged. This study also shows how modelling approaches could be used to minimize these impacts. For example, the model analysis showed that aflatoxin contamination could be minimised by growing early maturity cultivars, as well as through a late planting strategy to avoid high temperatures during the pod filling stage.

Media summary

Climate change, as demonstrated by a case study on peanuts in Australia, has the potential to adversely impact food safety in addition to food security.

Key Words

APSIM, aflatoxin, *Arachis,* groundnut, modelling

Introduction

Aflatoxin contamination of peanuts caused by *Aspergillus flavus* and *A. parasiticus* costs between $5 and 10 million per annum to the Australian industry in ensuring products marketed are well below the maximum permissible level of 15 μg/kg of this highly carcinogenic substance. In recent years these costs have been passed onto peanut growers to encourage them to adopt pre-harvest management practices that reduce the risk of contamination (Rachaputi et al. 2002). While these practices have been effective in years of moderate drought, severe end-of-season drought experienced over the past few years have meant aflatoxin contamination continues to be a major challenge for the industry. This, coupled with lower yields, has resulted in a sharp decline in the profitability of this crop, which is threatening the viability of the industry. It was therefore necessary to investigate the reasons for increased levels of contamination in order to develop more robust alternatives to minimize the contamination.

Production of aflatoxin by the aflatoxgenic fungi in the kernels depends on a combination of factors including temperature and moisture (Cotty and Jaime-Garcia, 2007). In view of the involvement of these climatic factors in aflatoxin production, it is possible that the increase in the risk in the last three decades or so could have been caused by climate change. There have been very limited studies on the potential impact of climate change on aflatoxin risk levels in peanuts.

A model to simulate risk of aflatoxin contamination in peanuts has been recently developed and validated in peanuts (Wright et al. 2005). The model was applied to analyse historical changes in risk of aflatoxin contamination in the dryland production region of Australia. The aim of this study was to examine: a) time trends in relation to ambient temperature, rainfall and radiation; a) effect of these variables on risk of aflatoxin and pod yield; and c) suggest possible solutions to minimise on-farm aflatoxin risk.

Materials and Methods

The Agricultural Production Systems Simulator's (APSIM,version 5.1) peanut module incorporating the aflatoxin model was used to simulate an aflatoxin risk index (ARI) as a measure of aflatoxin risk for medium maturing (~140 days) cultivar Streeton grown on Ferrosols containing 140 mm extractable water to a depth of 1.8 m at Kingaroy (-26^{o} 32'S 151^{o} 50'E) in south east Queensland, Australia from 1890 to 2007. Climatic data for the study were obtained from the silo website (www.nrw.qld.gov.au/silo). Time of planting of the crop was simulated whenever there was about 40 mm rain between 10 November and 15 January. If there was no such opportunity, the rule was relaxed to sow the crop with only 20 mm rain. Aflatoxin risk and pod yield were also simulated for a fixed sowing date (15-November) for the assessment of changes over a comparable period of growth. Daily means of maximum and minimum temperatures, solar radiation, in-season rainfall (from sowing to harvest dates) pod yield and ARI were the outputs generated for each crop season. The industry data on aflatoxin levels collected by the Peanut Company of Australia at the intake point from 1978 to 2007 was used to compute the proportion of aflatoxin positive loads for a given season, where a load recording >15 µg/kg of total aflatoxin was considered as a positive load. To validate the model ARI was regressed with the percentage of the observed aflatoxin positive peanut load in the corresponding season.

In order to assess the effects of planting dates and maturity of varieties, aflatoxin risk scenarios were generated for 15-November and 15-December sowings for a early maturity (VB97 type ~110 days) and a medium maturity cultivar (Streeton type) using the module. Probability distribution functions for scenarios were generated using the APSIM Outlook software.

Results

Aflatoxin risk and pod yield: The changes in ARI were linearly related with the extent of aflatoxin positive loads recorded in the region from 1978 to 2007 with an R^2 of 0.71 ($P<0.01$) being achieved, which provided a good validation for the peanut aflatoxin model (Fig. 1).

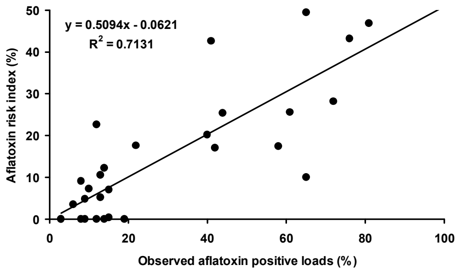

Fig. 1. Relationship between observed aflatoxin positive loads and aflatoxin risk index for Kingaroy from 1978 to 2007.

The average ARI simulated for the rule-based sowings from 1890 to 2007 was 6.1% during the pre-1980 period, whereas it was 17% during the post-1980 period (Table 1). In the pre-1980 period, there were about 44% of years free from any risk (ARI = 0), compared to only 19% such years in the post-1980 period (Fig. 2). A similar trend was seen with the fixed sowing date simulations (results not shown). Within the risky years since 1980, while the proportion of years with low risk (ARI > 0 ≤ 20%) was similar (~47%) compared to the pre-1980 period, the number of years with medium (ARI > 20 ≤ 50%) and high risk (ARI = 51-100%) more than tripled (9% vs. 33%). As a result, the combined risk of the medium and high categories, which was about 1 in 11 years during the pre-80 period, became 1 in 3 years. This trend was apparent with changes in the five yearly moving averages, which remained similar or higher than the overall average during the post-1980 period (Fig. 2). Pod yield was 11.7 % less during the post-1980 period compared to the pre-1980 period (Table 1).

Table 1: Averages of aflatoxin risk index (ARI), maximum and minimum temperatures, radiation, rain, and pod yield for a rule based sowing.

Period	ARI(%)	Temperature (^oC) Max.	Min.	Radiation (MJ/m^2)	Rain (mm)	Pod yield (t/ha)
All years	8.6	27.5	14.7	20.0	457	2.99
1890-1980 (a)	6.1	27.3	14.4	20.0	466	3.07
1980-07 (b)	17.0	27.9	15.5	20.0	428	2.72
(b − a)	10.9	0.6	1.1	0.0	−38	−0.35
% Change	126.7	2.1	7.4	0.0	−8	−11.70

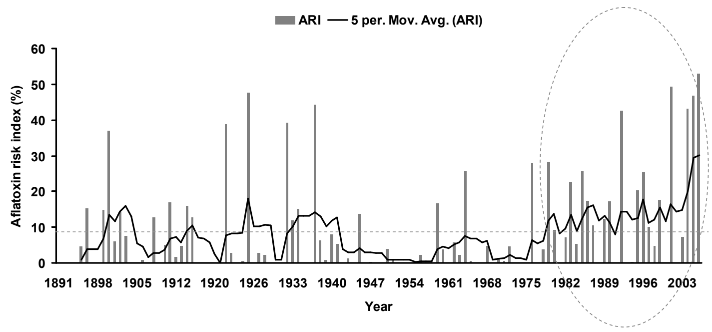

Fig. 2. Aflatoxin risk index (bars) and its 5 yearly moving average (solid line), and the overall average (horizontal dash line) from 1890 to 2007. The period after 1980 is encircled.

Climatic conditions: Mean maximum temperature during the post-1980 period was 0.6^oC (2.1%) higher than during the pre-1980 period (Table 1). Likewise, minimum temperature during the post-1980 period was 1.1^oC (7.4%) higher than during the pre-1980 period. Radiation was similar during these periods. During the post-1980 period the decline in rainfall was about 8%. For the fixed sowings on 15-November, maximum temperature was 0.25^oC (1.2%) higher and minimum temperature was 0.90 ^oC (5.9%) higher (data not shown).

Effect of sowing date and cultivar: The range in aflatoxin risk was largest with the 15-November sowing of early maturity cultivar, whereas it was smallest with the 15-December sowing of medium maturity cultivar (Fig. 3). With the 15-November sowing, the probability of positive aflatoxin risk 51% with the early maturity cultivar and 74% with the medium maturity cultivar. However, the probability of having aflatoxin risk under the 15-December sowing was reduced to a much greater extent in the medium maturity cultivar than in the early maturity cultivar. Mean pod yield was 2.5 t/ha of the early maturity cultivar compared to 3 t/ha of the medium maturity cultivar and was similar in the two sowings of the respective cultivar (data not shown).

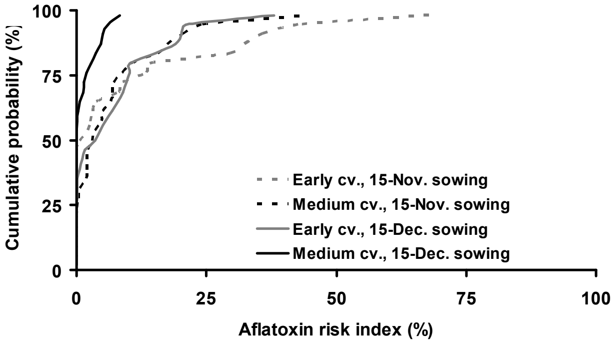

Fig. 3. Probability distribution functions of aflatoxin risk of early and medium-maturity cultivars planted on 15-November (usual time) and 15-December (late).

Discussion

The evidence presented here suggests that climate in the Kingaroy region has led to significant warming since 1980, especially during the nights. In conjunction with reducing rainfall, this has more than tripled the risk of aflatoxin and reduced pod yield in the region. The temporal difference in aflatoxin risk observed for this region is analogous to that noted previously between the warmer Coalstoun Lakes region, which has much higher risk, and relatively cooler Kingaroy with lower risk (Wright and Hansen 1997). Our study therefore suggests that increases in aflatoxin risk seem imminent in the face of climate change.

Our study also suggests that the risk caused by climate change could be significantly lowered by the adoption of different agronomic strategies. The main approach could be to reduce the exposure of the crop to terminal stress by adopting a combination of early maturing cultivars in early sowings or to high temperature by a full season maturity cultivar in late sowings without a significant yield penalty. Modelling approaches could assist in exploring these options.

Conclusion

The model simulations have shown that aflatoxin risk has increased appreciably and pod yields have declined since 1980 due to higher temperature and lower rainfall associated with climate change. The study suggests that modelling approaches could be used to explore on-farm solutions to minimize aflatoxin risk in peanuts.

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