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Poisoned Chalice:

Toxin Accumulation in Crops in the Era of Climate Change

Climate changes trigger accumulation of toxins in crops

Climate change is already underway, with shifting weather patterns that will present serious challenges to agricultural productivity. Each of the past several decades has been significantly warmer than the previous one. The period 2011–2015 was the hottest on record, and 2015 was the hottest year since modern observations began in the late 1800s.[1] The 2013 global assessment released by the Intergovernmental Panel on Climate Change reports that since 1950 the frequency of heat waves has increased in large parts of Europe, Asia, and Australia; that the frequency and intensity of droughts have increased in the Mediterranean and West Africa; and that the frequency and intensity of heavy precipitation events are likely to increase in North America and Europe.[2]

Given that more than 70 per cent of agricultural production relies on rainfall, increasing climate variability poses an unprecedented challenge to agriculture and to food production systems around the world.[3] Climate threats to food security are expected to be worse in countries at subtropical and tropical latitudes.[4] For instance, the frequency, severity, and range of droughts in the entire African continent have significantly increased between 1900 and 2013.[5,6] Specifically in East Africa, the well-documented 2010–2011 drought greatly affected agricultural yield and increased food insecurity in the region.[7] In 2015-2016, El Niño-related dry conditions reduced crop production in parts of Asia, Central America, the Caribbean, and Oceania, while drought conditions in East and Southern Africa resulted in decreased cereal production.[8] Analysis of detailed crop statistics time series suggests that between 32-39 per cent of the fluctuations in observed global crop yield is a direct result of climate variability, particularly for maize, rice, wheat, and soybean.[9]

Extreme climatic conditions reduce yields and increase postharvest losses. They also trigger biophysical reactions in plants in response to environmental stresses. These reactions include concentrating chemical compounds that are harmful to animal and human health. Despite a plant's various protective responses, in prolonged unfavourable conditions stress can overwhelm its ability to thrive, and can weaken the plant further, leading to increased disease susceptibility. In such cases, either the plant itself or invading microbes can produce specific chemical compounds at levels toxic to human health.

Video: A dry season

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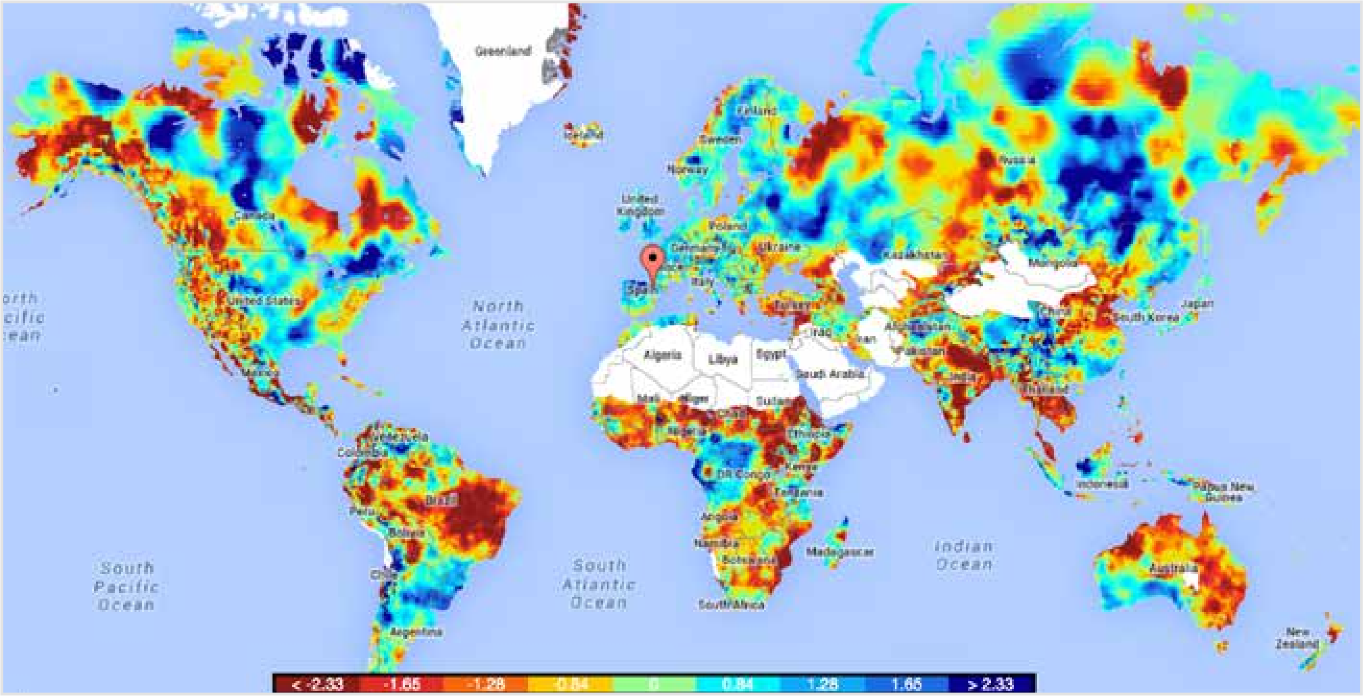
SPEI Global drought map



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http://sac.csic.es/spei/map/maps.html

Contamination pathways–implications for crops, animals, and people

Worldwide, over 80 plant species are known to cause poisoning from accumulation of nitrates.[10] Under normal growing condition, plants convert nitrate into amino acids and protein. Drought conditions slow or prevent the conversion, causing nitrate to accumulate indefinitely to the level that becomes toxic to animals.[11] Common crop plants most susceptible to nitrate accumulation are barley, maize, millet, millet, maize, sorghum, soybean, sudangrass, and wheat.[12] When cattle, sheep, and goats consume large quantities of high nitrate plants, their ruminant digestive processes cannot break down the nitrate fast enough to avoid poisoning. Acute nitrate poisoning in animals can lead to miscarriage, asphyxiation, and death. Nitrate poisoning in livestock can ruin the livelihoods of smallholder farmers and herders.

Sufficient rain can revitalize plant growth and help reduce nitrate accumulation. However, after a drought-breaking rainfall or irrigation inflow, rapid growth in water-stressed plants could result in dangerous accumulation of another toxic compound called hydrogen cyanide or prussic acid.[13] Examples of plants that can accumulate prussic acid are cassava, flax, maize, sorghum, sudangrass, arrow grass, velvet grass, apricot, peach, cherry, elderberry, and apple.[12]

Another important category of toxin associated with changing climate is mycotoxins, chemical by-products of fungal growth. Mycotoxins can cause severe damage to the health of animals and humans even at small concentration. Mycotoxin-producing fungi infect many crops such as coffee, groundnut, maize, oilseeds, peanut, sorghum, tree nuts, and wheat. An estimate in 1998 suggested that mycotoxins contaminated at least 25 per cent of cereals worldwide[14,15]

Aflatoxins are a type of mycotoxin produced by a species of Aspergillus fungi. About 4.5 billion people in developing countries are exposed to uncontrolled and unmonitored amounts of aflatoxins.[16] Acute exposure can be lethal, while chronic exposure can lead to cancer. Evidence further suggests it may also stunt foetal and infant development, block nutrient uptake, and suppress immunity.[17] Poorer farmers may feed mouldy grains to livestock, but this is not a safe option. Aflatoxins and other mycotoxin contaminants can reduce animal productivity and increase mortality, and they can persist in animal-sourced food products such as milk to impair human health and nutritional status.[18]

Photo Credit: UN Photo/James Bu

A study of aflatoxin occurrence in Serbian maize confirms that the contamination detected in the 2012 maize harvest resulted from that year's prolonged warm weather and extreme drought conditions.[19] Normally, environmental and climatic conditions in Serbia and other temperate regions do not favour the growth of aflatoxins, in contrast to tropical and sub-tropical zones where aflatoxin contamination is more evident.[20] However, the risk of aflatoxin contamination, particularly in maize, is expected to increase in higher latitudes due to rising temperature. A recent model study predicts that aflatoxin in maize will become a food safety issue for Europe, especially in the most likely scenario of a 2°C increase in global temperature. Areas at high risk of aflatoxin outbreaks include Eastern Europe, the Balkan Peninsula, and the Mediterranean.[21]

Video: Nitrate Toxicity in Corn

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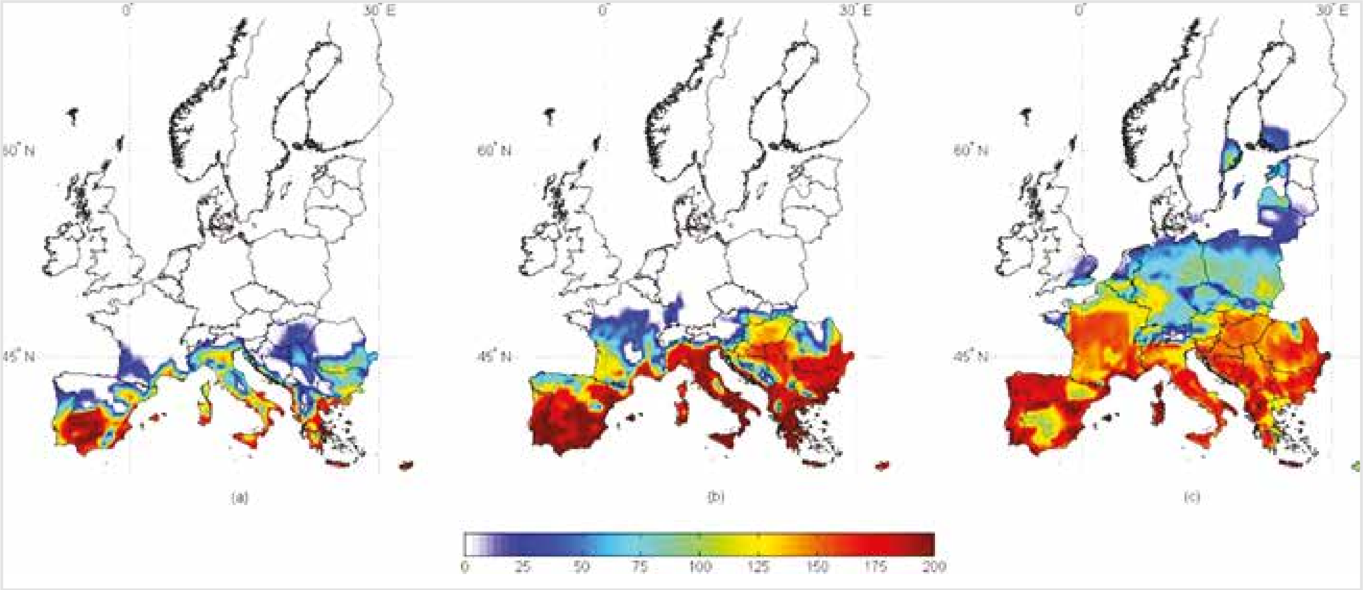
Video Link: https://www.youtube.com/watch?v=GguOOGzeOWk
Photo Credit: Kent Weakley/ Shutterstock.com

Risk maps for aflatoxin contamination in maize at harvest in 3 different climate scenarios, present, +2 °C, +5 °C



Source: Battilani *et al.* (2016)[21]
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Remediating toxic contamination in plants and animals

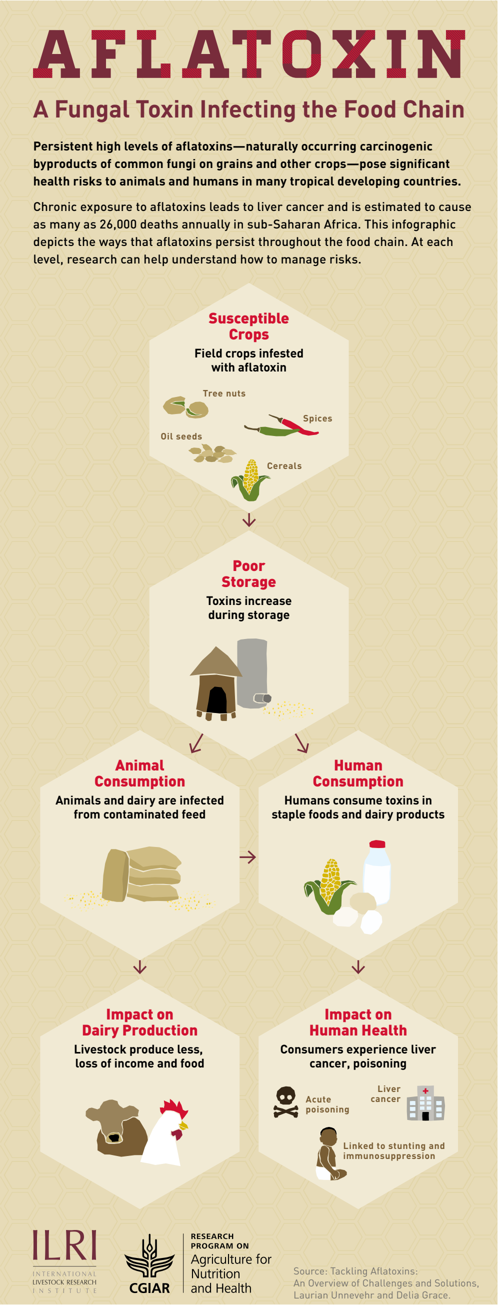
We are just beginning to recognize the magnitude of toxin-related issues confronting farmers in developing countries of the tropics and sub-tropics. As warmer climate zones expand towards the poles, countries in more temperate regions are facing new threats.[21-23] Deteriorating climatic conditions combine with enhanced capacities of diagnostic surveys for toxin detection to reveal that more and more global food stocks appear to be at risk of contamination. The effects of other environmental cues on plant-pathogen interactions or on a plant's own biochemical responses have yet to be resolved.[24-25] However, it is clear that more extreme environmental conditions can trigger toxin accumulation in crops. The ability to detect these toxins is becoming less expensive and more mobile, which will help ensure that the food being produced and consumed is safe.

Growing recognition of these challenges has prompted a range of efforts to understand, prioritize, and respond. In at-risk regions, an important start has been made on programmes to increase productivity and reliability of crops that are less susceptible to toxin contamination. These are combined with drought and disease surveillance programs and warning systems.[26-27] Such mutually reinforcing efforts can help deploy effective strategies and targeted rapid responses to outbreaks when climatic conditions become severe.

At the global and regional level, relevant programmes are underway: the Comprehensive African Agricultural Development Program; the African Union Commission's Partnership for Aflatoxin Control in Africa (PACA); food safety and regulation efforts by the UN Food and Agriculture Organisation (FAO), the World Food Programme, and the World Health Organization; and the 2030 global agenda for sustainable development with a specific sustainable development goal seeking to "end hunger, achieve food security and improved nutrition, and promote sustainable agriculture."[28]

A growing number of projects are applying science-based solutions to address these health and development challenges. Examples include accelerating the international network of National Agricultural Research Systems (NARS)–supported by FAO, the Consultative Group for International Agricultural Research (CGIAR), and their constituent agencies–as well as international plant breeding efforts and technologies; bio-control strategies to apply natural antagonists of toxin-producing fungi in farmers' fields, proper postharvest drying and storage; and development of mobile diagnostics and decontamination.[29,30] Risk assessment and mapping is a powerful tool for decision making based on an understanding of various aspects of contamination risk.[26,31] Some research focuses on strategies to develop more varied drought-tolerant or disease-resistant crops, including genome editing to eliminate genetic elements underlying susceptibility to risky diseases or toxins; transformation with disease resistance, drought tolerance, or toxin-degrading genes; and characterization of available agro-biodiversity options for on-farm production, for both the crop itself and the microbial communities influencing productivity and stress tolerance.[32]

Photo Credit: Smereka/ Shutterstock.com



AFLATOXIN

A Fungal Toxin Infecting the Food Chain

Persistent high levels of aflatoxins—naturally occurring carcinogenic byproducts of common fungi on grains and other crops—pose significant health risks to animals and humans in many tropical developing countries.

Chronic exposure to aflatoxins leads to liver cancer and is estimated to cause as many as 26,000 deaths annually in sub-Saharan Africa. This infographic depicts the ways that aflatoxins persist throughout the food chain. At each level, research can help understand how to manage risks.

Susceptible Crops
Field crops infested with aflatoxin

Tree nuts
Spices
Oil seeds
Cereals

Poor Storage
Toxins increase during storage

Animal Consumption
Animals and dairy are infected from contaminated feed

Human Consumption
Humans consume toxins in staple foods and dairy products

Impact on Dairy Production
Livestock produce less, loss of income and food

Impact on Human Health
Consumers experience liver cancer, poisoning

Acute poisoning
Liver cancer
Linked to stunting and immunosuppression

ILRI
INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

CGIAR

RESEARCH PROGRAM ON
Agriculture for Nutrition and Health

Source: Tackling Aflatoxins: An Overview of Challenges and Solutions, Laurian Unnevehr and Delia Grace.

Source: © ILRI

Video: Aflatoxin contamination in Kenya

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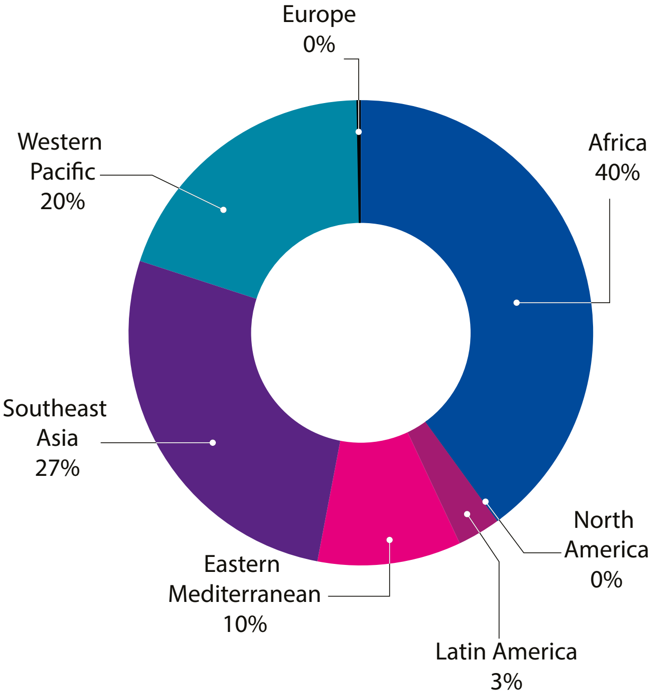
Distribution of liver cancer cases attributable to aflatoxin in different regions of the world



Data Source: Liu and Wu (2010)[34]

Integrated approaches to meet the challenge

As farmers and consumers the world over face increasing challenges to boost food production, an aggressive strategy to safeguard agricultural yields in drought-prone areas is an essential part of efforts to safely feed the world's growing population. Mitigation strategies are being resolved, tested, and scaled up. These efforts must be significantly expanded and accelerated to secure a safe harvest for current and future generations.[33]

National and regional agricultural systems – from research to extension to policy and regulatory – must be engaged and strengthened to sustainably address these complex challenges at appropriate intervention points. A number of critical elements are lacking today that can be addressed through such strategically inclusive and integrated research for development systems.

1. Building the evidence base for the prevalence and human health implication of various toxins, particularly for long-term exposure to sub-acute levels of toxins in the diet.
2. Recognising the interactions between animal health, human health, and the environment and addressing the issue in the context of One Health and EcoHealth approaches.
3. Characterizing and modelling the factors affecting toxins' accumulation in different crops, and identifying mitigation measures that are effective, adoptable, and scalable within different farming and agroecological systems.
4. Prospecting existing or traditional on-farm practices for solutions.
5. Reducing production and postharvest risk with best practice interventions.
6. Using risk assessment and mapping to predict contamination hotspots and assess mitigation options.
7. Advancing and deploying mobile testing, and incentivizing farmers by providing an alternative-use market for contaminated products where possible.
8. Continuing research to continually evolve options to produce a sufficient and safe harvest in marginal areas around the world.

Technology solutions must work in concert with stakeholder consultations and be supported by agricultural field extension in rural communities. Appropriate and effective capacity building at various levels must underpin intervention deployment. Equipped with a rapidly increasing understanding of the hidden dangers of crop production under changing climate, we must work to secure a sufficient and safe harvest for all.

Video: **Intiatives to tackle the aflatoxin contamination in Africa**

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