Meeting Summary Report

Mycotoxin predictive modelling online meeting, 26 October, 2020

Contents

Welcome and Meeting Objectives

- The meeting was co-organized by the Joint Research Centre of the European Commission, the Mycokey Project, The Mytox-South Network and the APHLIS project. It was moderated by Felix Rembold of JRC's Food Security Unit (D5). The unit initiated the APHLIS project many years ago and is dealing with crop production monitoring and crop growth modelling for food security.
- Knowledge about Mycotoxins occurrence and risk prediction is key for agriculture, food security, food safety and health policies, especially in food insecure countries. Various predictive models have been proposed by crop modelers, but none of these models is currently used operationally at national or regional scale in Africa.
- Food safety risks are increasing with climate change are require urgent action and policy dialogue to protect citizen's health and to help farmers for producing high quality crops. The European Union´s new Farm to Fork strategy in the Green Deal proposal recognizes the importance of food safety not only for food imports into the European Union, but confirms also its central role for the Sustainability of Food Systems at the Global level.

- The scope of the present meeting is to understand where we are, what is needed and what is missing in the field of predictive modelling for African countries. The meeting is a first step to start this discussion in view of future events such as an EC internal meeting on Sustainable food systems (Nov. 27) and the 2021 Conference of the African Society of Mycotoxicology. Also it builds on the experience of the Mycokey project and the Mytox-South Network.

Part I: Keynote Presentations

Two MYCOKEY (Antonio F. Logrieco coordinator) contributions on mycotoxin predictive modelling for Fusarium Head Blight and deoxynivalenol on wheat and *Aspergillus flavus* and aflatoxin B1 on maize :

Plant disease forecasting using data mining and machine learning: a case study on Fusarium head blight and deoxynivalenol in winter wheat - Sofie Landschoot, Ghent University

The presentation focused mainly on the development of Fusarium species prediction for wheat in Europe and the research shown is part of the Mycokey project.

- Description of the three main steps in model building:
    - data collection and data mining;
    - machine learning using metric regression techniques to predict output variables (examples given for continuous output variable (e.g. toxin content), ordinal output variable (e.g. disease classes), categorical output variable (e.g. distribution of Fusarium species)
    - model validation – which parameters and how well the model will perform in future (new years and new locations)
- Case study of Fusarium Head Blight (FHB) –
    - highlighting how incidence of visual symptoms and DON content vary by years, and noting there is not always a good link between toxins and visible symptoms;
    - data mining to determine correlation between disease symptoms and DON content with weather conditions at different points in the crop cycle (ie early, flowering etc)
    - influence of agronomic factors
    - Although DON is a continuous variable, good predictive results were not obtained so then attempted to predict DON content using 4 classes based on the EU limits. But it was not possible to use the 125ppm threshold for unprocessed crops as so few samples exceeding this threshold.

Flexible predictive models for mycotoxin in maize, useful at global level and in climate change scenarios - Paola Battilani, Università Cattolica del Sacro cuore, Piacenza

Prof. Battilani provided an overview of mechanistic models developed for the prediction of Aspergillus infection and of Aflatoxin B1 production in maize with some hypothesis on how climate change will affect the development and habitat of those mycotoxins in Europe and Africa.

- Mechanistic model for Aspergillus flavus production of aflatoxin B1 in maize, based on each stage of the infection cycle. This is a flexible approach that can be used for different geographic areas and on different crops. Model has divided two parts: one for the fungus, one for the crop. Model workflow: data collection, model development, validation, improvement.
- Using the temperature and Aw can predict the sporulation or the mycotoxin production on a daily basis. Model Input: hourly meteorological data. Model output: daily Aflatoxin/Fumonisin Index (AFI/FUMI). Put the functions together to build the model, and then need to validate the model
- Model enables visualisation of how the day by day risk of contamination grows during the season, and can also use historic data to predict potential risk which can be used to support farmers and other stakeholders decisions
- Climatic change projections on future scenarios – eg. Risk map of AF in maize for southern Europe with a +2C and +5C average warming. Can highlight hotspots for AF in maize.
- Transfer of model to other crops, ie Pistachio in Greece found 72% correct prediction
- Work by a PhD student in Malawi – applied this predictive model to maize looking at different climate change scenarios, different cultivars and sowing dates – outputs suggest the aflatoxin situation will be much worse in future, particularly for late sown crop
- Potential service for farmers:
  Historical data = past scenarios
  Present data = on-going risks
  Future data = climate change scenarios (EFSA project)

MyToolBox DSS for storage of grains and nuts in China and early forecasting in Europe - with suggestions as to how these techniques could potentially be used/transferred to Africa, My ToolBox – Rudolf Krska, MyToolBox coordinator and President of the International Society for Mycotoxicology

The presentation addressed mainly the postharvest management aspects of the MyToolBox project experience from China and Europe related to mycotoxins information that could be relevant for Africa:

- The project looked at a range of mycotoxin management practices, sorting, atoxigenic fungi, recombinant enzymes to detoxify mycotoxins etc. Particularly focus on Fusarium toxins but also work on biocontrol of aflatoxins.
- Established a real-time postharvest environmental monitoring system for storage of cereals, and linked physical data with biological models of ZEN, OTA and aflatoxin production – calculated dry matter losses linked to environmental conditions during storage.
- Installed CO2, T and RH sensors in large grain silos (each with a 6,000 tonne capacity) near Beijing. Found that CO2 was an earlier and better indicator that temperature rise as grains are good insulators. Developed traffic light warnings and decision-support systems for peanuts (China), and maize (Barilla). If system gives yellow or red alert then need to remove the grains from the system of spray fungicide. Although considerable information on Good Agricultural Practices (GAPs) exists, much of it is in technical documents and not in a user-

friendly format – this needs simplifying to support e-platform content accessible to farmers and decision-makers by phone or laptop

Mycotoxin prediction modelling @Mytoolbox – Ine van der Fels-Klerx, Wageningen Food Safety Research Unit

Dr. Fels-Klerx presentation is also part of the My Tool Box projects but addressed harvest time mycotoxins modelling in Europe.

- Modelled for mycotoxins in maize and wheat using empirical models, mechanistic models and machine learning. Combining mechanistic (as presented by Paola) and machine learning modelling was found to provide the best accuracy.
- Model accuracy validation was high: 84% for aflatoxin in maize, 80% for fumonisin in maize
- MyToolbox E-platform – mobile phone app for decision support in mycotoxin management. Farmer enters their details on the app on their phone: location, agronomics etc and then gets a warning based on the predictive risk of mycotoxin – this risk is updated each day. The farmer also gets advised on what management action to then take.
- No models for Aflatoxin prediction currently available in Africa that have been validated or are commercially run. An important challenge is the availability of data to calibrate and test the model.

International cooperation: MYTOX-SOUTH partnership to improve food security and food safety – Sarah De Saeger, coordinator MYTOX-SOUTH

Prof. De Saeger presented a comprehensive overview about existing research partnerships with African countries for improved food safety, based on the Mytox-South Project experience:

- The presentation opened with an awareness raising video on mycotoxins and their public health and socio-economic impacts – https://vimeo.com/375702193/08bb302729
- Overview of the Mytox-South project coordinated by Ghent University – Partners: Kenya, Nigeria, Zimbabwe, Malawi, Ethiopia, South Africa, Tanzania, Uganda, Argentina and PAEPARD. Three main aims of Mytox-South:
    - Education and training of young students and scientist from LMICs – building capacity through co-creation. Traineeship periods (1 to 6 months)
    - Awareness creation – networking/ partnerships – including events to discuss mycotoxin issues at higher levels e.g. in Zimbabwe and Nigeria recently; and awareness creation with farmers e.g. in Feb 2020 with Soweto farmers
    - Conducting research and developing innovative technologies in terms of suitable mitigation strategies. Projects include: LEAP-Agri; MYCO-SAFE South, World Bank grant (African Centre of Excellence (ACE) for Mycotoxin and Food Safety Research in Africa; ERC StG HuMyco;
- To make progress in mycotoxin and food safety management, we need: interdisciplinary research and development, co-creation, an international approach, outreach and debate with different policy makers, farmers, scientists

African Postharvest Losses Information System - Mycotoxin Agro-climatic Risk Warnings - Felix Rembold, Joint Research Centre of the European Commission

The presentation gave a quick overview of the preliminary results achieved by the APHLIS project in agro-climatic mycotoxin risk warning.

- APHLIS www.aphlis.net was created in 2009 focussing mainly on levels of physical losses occurring, but in the latest stage there has been some exploratory work on risk warning for mycotoxins
- Data availability for calibration and validation of the model is challenging, but some other parts of the modelling are easier, e.g. temperature in Africa is less of a limiting factor for mycotoxins development than in other parts of the world
- Based on the previous research on mycotoxins prediction models like those presented by Prof. Battilani and the Australian team of Prof. Chauhan, near real time agro-climatic variables from early warning systems at the level of administrative areas were used, such as drought stress during maize grain filling stage, and high moisture levels around harvest
- Risk analysis maps released every 10 days can be informative to understand where pre-harvest agro-climatic conditions make the development of mycotoxins later in the crop cycle or after harvest more likely. This agro-climatic risk for mycotoxin mapping work has not been validated as we haven't been able to find sufficient validation data, also it is difficult to do validation at the aggregated level of admin. areas
- The risk maps are not publicly available on the website, and are in a restricted section – but any participants interested in them should contact Felix for access.

Part II: Participants roundtable and discussion

Participants in the roundtable discussion had been invited to provide reflections and inputs to the discussion related to 3 lead questions:

1. Are you aware of research on/implementation of mycotoxin predictive modelling in your focal country/continent?

2. What is needed from your perspective to build better predictive mycotoxin models for African countries and to implement them?

3. Specific priorities related to mycotoxin predictive modelling for your institution (academia, govt., int. development)

Sheila Okoth, African Society of Mycotoxicology
Note: 3rd Symposium of the African Society of Mycotoxicology will be held in Sept 2021

1. I'm aware of two types of model: In East Africa, we have the APSIM – maize growth, yield and soil water balance – model which was used to predict the impact of drought conditions on aflatoxin in maize and was trialled in Kenya in 2015 – but has not been taken forward for adoption. Also risk maps have been drawn using geographical information and geostatistics

(e.g. by ILRI and IFPRI-Maxent program) – but those maps have been published and that is the end of the story. AVHRR satellite data and crop simulation model in Mali.

2. We need to ask – **who are we modelling for**, is it just for policy makers or for farmers, and if for farmers can we also come up with guidelines for what farmers at high risk should then do

--

Amare Ayalew, African Union, Partnership for Aflatoxin Control in Africa

1. The major effort that I know of is the aflatoxin forecasting model developed by Mars Incorporated, FAO and Univ. of Cambridge for maize. I think that model has progressed to evaluation stage and was being tested in Tanzania.
2. a) I do think the first thing is giving more attention to prediction models in Africa in the first place. I thank the organizers for picking the topic for this webinar. We should keep the momentum. b) In my view what we need is a model that can provide risk guidance to apply management options. I can see the value of such a tool in aflatoxin control. Aflatoxin occurs pre and postharvest and requires preseason, preharvest and postharvest measures for effective management. Such a tool can really improve our ability to choose and target interventions. c) Since there is no one size fits of all model, I think we should try to capture the varied situations in Africa.
3. a) I do think we should prioritize generation of trustworthy data on mycotoxins, climatic factors and satellite imagery when possible for the different agroecological regions and priority crops in Africa. **Data gap seems to be the major constraint** why Africa lags behind in mycotoxin prediction models. b) We also need collaboration among multi-disciplinary groups and including groups that have practical experience since modeling expertise is not widely available within Africa.

--

Dan Makumbi, CIMMYT CGIAR Kenya

1. Mycotoxin prediction models have not been utilised in Africa
2. To build robust models – we need a larger database of mycotoxin prevalence in pre-harvest and post-harvest data. **Also we need to improve capacity on modelling**. In relation to the building of models – an important thing is reliable weather data, which are not easily available nor accessible – this may require support for affordable data stations.
3. **Aflatoxin models are resource demanding** so we need to look into options to make quantification of aflatoxin more accessible.

--

Hussaini Makun, Coordinator of the World Bank ACE in Mycotoxin and Food Safety (ACEMFS)
The ACE was established by a WB grant by the WB and the Federal Govt of Nigeria and the idea is to improve on postgraduate studies in the country. Our major thrust is the health impact of food toxicants, and to build a centre for mycotoxins, heavy metals, pesticide residues, food borne toxicants. We Have launched 3 courses on food safety and toxicology and run short courses.

1. FAO and others, including APHLIS, have put some effort into developing Food Safety Early Warning Systems in Africa, **but the systems have not yet been validated**.
2. To improve on these models in Africa requires capacity (there is an absolute lack of capacity in both industry and academia) – we have 1 PhD and 2 MSc students working on that. In the ACEMFS we are not well equipped with Machine Learning capacity etc to generate these models, so we are glad of the partnership to help get supervision of students to work in this area, and hopefully will help attract some funds to work in this area.
3. **The critical things are capacity building and funds**.

--

Marie Krottenthaler and Shahid Minhas, World Food Programme (WFP)

Marie highlighted that she is responsible for audits and aflatoxins are included in suppliers audit assessment and it is an area of real concern.

Shahid Minhas has recently joined the WFP Food Safety and Quality office in southern Africa. Quality of the product that WFP purchase is really important, and WFP have a lot of purchasing contracts in place. Have seen trends of high aflatoxin content in some of the finished product, so there is a need to look at the data with the supply community not only on postharvest aspects but on the climate.

There is a lot of data on maize crop quality surveys available for southern Africa. But there is a gap between those models and data at the Govt level, it is not only WFP who would benefit from these models but also the communities producing and consuming the crops. For any models there would need to be good coordination with the farmers, institutions and academia. Capacity needs to be increased.

--

Habiba H. Wassef, African Nutritional Society

The SMART Ag tool shown is very interesting.

What about the health impacts can we also predict those in the model?

Capacity building in Africa for predictive modelling is very weak. We need to strengthen that in all our institutions.

Worried that **Covid-19 impacts** are increasing food security and poverty across many African countries, this is a particular concern given that it is often said poor smallholder farmers can't afford to get rid of poor quality grains and so have to consume them, this poverty increase will increase this problem

--

John Leslie, Kansas State University, USA

1. Most of the models I have seen that have been successful, have been based on weather data so **I would be very happy if we could get sufficient weather data to input to the models**.
2. **Many of these models are insensitive to varieties**. Many of the crops grown in Africa are local varieties and not standards so we will need to build that into the models. Our DON and Fusarium head blight modelling system is pretty good but that is much simpler to model as it doesn't have insect interaction.
3. How do we get to the point where we have the data that we need to rely on?

--

David Miller, Carleton University, Canada

The Province of Ontario produces 2.5 million tonnes of wheat and 95 million tonnes of grain corn annually. **We use a model called DONcast, it is based on weather data from little weather stations, but also relies on field surveys for mycotoxins in the crop**– and for the last 30 years these have been done. For reasons noted by Dr. Leslie, the changing of cultivars affects the algorithms so the models algorithm literally needs to be updated every year. This is very expensive to do. The DONcast model is fully commercial.

In the U.S. and in Canada around 250 million dollars is spent doing analysis of mycotoxins, and in a bad year a lot more is spent than that, so **it takes a huge amount of resources**.

For Aflatoxin and Fumonisin – field scout data is mainly used to make agronomic decisions for the season and the models are not so important.

With my colleague Dr. Gerado Morales from Buhler and some others, we started to think outside the box. Africa leap frogged into cellular networks by passing other approaches used in the fully developed market economies before cell networks. There have been some innovations in satellite particularly to use very high resolution capacity on for example water information from Radar sensors – Canada flies three of these satellites

U.S. and Canada have access to a large and long time series database on Aflatoxins and Fumonisins and other toxins. Work at the moment is focused on how can we build an algorithm using US, Canadian and EU data on mycotoxins to build a model that works in Africa.

--

Frans Verstraete, EC DG Sante

I am aware of research on mycotoxin predictive modelling (Mycotox and Mytoolbox), but there are also a lot of other initiatives.

In predictive models you have to separate two types, those that predict risk of high levels of mycotoxins in a region (which can be used for management at regional level), and those that are predictive modelling to support an individual farmer to make decisions in a preventive way

Need to think about an integrated model, as no point being protected against one mycotoxin if you are then at risk of another mycotoxin.

Need models that clearly separate predictions on regional models (based on weather – so you know where to be extra vigilant and make link with health risk), then models for individual farmers to take the right decisions to reduce risk (varieties, agronomic practices and timing etc)

The issue regarding locally specific variety specificity of models is an important challenge

--

John Lamb, Agragen

1. There is a need for continuing and increased effort to communicate and raise awareness with people who are not within the mycotoxin community, especially currently given the very competitive funding situation due to Covid-19
2. Possibly the need to be thinking more broadly in terms of the crop coverage, so not just maize and peanuts, and no mention was made of animal feed so that aspect is missing
3. Need to tailor the messaging in a different way – as a group interested in mycotoxins we need to be aware of donor fatigue and given the focus more towards global and animal health as opposed to plant health

Part III: Final discussion around the following main questions:

The discussion was moderated by **Antonio F. Logrieco** (CNR-ISPA, Italy) who opened starting with the following questions:

1. Do you think that predictive models can help reduce or prevent mycotoxins?
2. Do models exist that can be adapted to Africa, and how could they be validated? What data are needed?
3. Which crops and value chains need to be better looked at?
4. What resources exist for improved mycotoxins prediction?

Discussion:

Antonio Logrieco: Which model to use as different models already exist in US, Canada etc.? Do we need efforts to validate these different models? The situation with maize differs – as the mycotoxins differ – aflatoxin and then fumonisin. The mycotoxins can be produced at different crop growth stages.

John Leslie – a crop not mentioned today that is hugely important is sorghum (in US it's the 3rd or 4th most important crop) but in many parts of the Sahel and SSA sorghum and millets are the crops we should be thinking about as they are so important in the food systems there.

Sarah De Saeger – availability of data – this is beyond data for predictive model, there is generally a problem related to mycotoxin occurrence data from Africa. Monitoring data from many years is not in place yet. We checked the FAO GEMS data but it is not sufficient. There is a lot of data but it is all scattered everywhere in papers etc – we are trying within MYTOX-SOUTH to create a platform for this.

David Miller – sorghum, peanuts, cowpeas, teff, cassava – all important crops in food systems in Africa. My own bias here. Ron Knightley and I said a long time ago we need to do better with this so we can tell agencies such as the WFP where they may get a problem. But we need to note that if the USA (a country that can put a man on the moon) cannot solve fumonisin etc but instead learns to manage it, then it is probable these issues can't be solved in Africa but can be managed. Improving dietary diversity is one of the management tools we have on the table.

Ine van der Fels-Klerx - There are different species of fungi, and Africa is a large and diverse area, so the only way to go is through collaborations - we need to downscale and start bottom up and work in a few countries and if something works then spread out to other areas.

Paola Battilani - It is important to remember **that data collection on mycotoxins must be geo referenced**, otherwise the data can't be used in a model. If we have meteorological data we can have an idea of the risk based just on met factors , if we have contamination data then we can ground truth.

Questions sent via Chat function

from Naresh Magan:

The resilience of mycotoxigenic fungi is differential to climate change factors. This may influence the types of mixtures of mycotoxins which might occur. Do the predictive models take this into account or can they be appropriately modified??

Predictive models will never be used by small rural farmers in Africa. This is only accessible to large scale farmers or co-operatives. Thus as David Miller has said effective management is the key approach.

Please consider upfront the pathway of implementation of successfully developed forecasting models. Identify the partners who would help in implementation

IITA has a lot of georeferenced data on aflatoxin in several African countries that we can share for the modelling exercise

from J David Miller:

In one population we have looked at, there were exposures based on biomarkers with labelled standards to aflatoxin, zearalenone and DON rather less so to fumonisin.

Annex 1: Detailed agenda

Time	Item	Presenter
Introduction		
14:00 - 14:05	Welcome and introduction	Felix Rembold
Keynote presentations		
14:05 - 14:20	Mycokey: Holistic modelling: a powerful tool to predict mycotoxins in small grain cereals, by Sofie Landschoot Flexible predictive models for mycotoxin in maize, useful at global level and in climate change scenarios, by Paola Battilani	**Sofie Landschoot** - Ghent University **Paola Battilani** - Università Cattolica del Sacro Cuore, Piacenza
14:20 – 14:35	MyToolBox DSS for storage of grains and nuts in China and early forecasting in Europe - with suggestions as to how these techniques could potentially be used/transferred to Africa, My ToolBox – by Rudolf Krska	**Rudolf Krska** - MyToolBox coordinator and President of the International Society for Mycotoxicology
14:35 – 14:45	International cooperation: MYTOX-SOUTH partnership to improve food security & food safety- by Sarah De Saeger	**Sarah De Saeger** - coordinator MYTOX-SOUTH
14:45 – 14:55	African Postharvest Losses Information System - Mycotoxin risk warnings, by Felix Rembold	**Felix Rembold** – Joint Research Centre of the European Commission
14:55-15:00	Questions to the presenters	
Participants roundtable and discussion		
15:00 - 15:30	Round of 3 minutes short replies to the following questions from different institutional perspectives (academia/research (Universities, ASM, CGIAR), government/policy (AU,	Proposed speakers: 1. **Sheila Okoth**, African Society of Mycotoxicology

	EU), international development agencies (WFP): 1.) Are you aware of research on/implementation of mycotoxin predictive modelling in your focal country/continent? 2.) What is needed from your perspective to build better predictive mycotoxin models for African countries and to implement them? 3.) Specific priorities related to mycotoxin predictive modelling for your institution (academia, govt., int. development)	2. **Amare Ayalew**, AU PACA 3. **Dan Makumbi**, CYMMIT CGIAR 4. **Hussaini Makun**, ACEMFS 5. **Marie Krottenthaler**, WFP 6. **H.H. Wassef**, African Nutritional Society 7. **John Leslie**, Kansas State University, USA 8. **David Miller**, Carleton University, Canada 9. **Frans Verstraete**, EC DG Sante 10. **John Lamb**, Agragen
15:30 – 16:00	Final discussion about the following main questions: 1.) Do you think that predictive models can help reduce or prevent mycotoxins ? 2.) Do models exist that can be adapted to Africa, and how could they be validated? What data are needed? 3.) Which crops and value chains need to be better looked at? 4.) What resources exist for improved mycotoxins prediction? Messages for future events (Brussels meeting and ASM Mytox South Conference)	Moderator: Antonio Logrieco, CNR-ISPA MycoKey Coordinator
Conclusions		
16:00–16:05	Wrap-up	Felix Rembold

Annex 2: Participants list

Alejandro Ortega-Beltran
Antonio Logrieco
Antonio Moretti
Brighton Mvumi
Bruno Tran
Bruno DECLERCQ
Caroline Mwendwa
Dan Makumbi
David Miller
Deblina Sarkar
Hanneke Alberts
Meshack Obonyo
Erika Warnatzsch
Felix REMBOLD
Frans Verstraete
Gerardo Morantes
Habiba Hassan-Wassef
Hussaini Makun
Ine van der Fels-Klerx
Joerg Stroka
John Leslie
John E Lamb
Lucy Mabuga
Mannara Charles
Marie Krottenthaler
Martin E. Kimanya
Monica ermolli
Naresh Magan
NGounou Batchanji Steve
Oluwafemi Adebo
Paola Battilani
Professor Ben Bennett
Ranajit Bandyopadhyay
Rudi Krska
Sarah De Saeger
Shahid Minhas
Sheila Okoth
Tanya Stathers
Thierry Negre
Tobias Aduda
Virginia Siebenrok
Yves Severin Rwigimba