



Mycotoxin Reduction in Grain Chains



John F. Leslie & Antonio F. Logrieco

WILEY Blackwell

Mycotoxin Reduction in Grain Chains

Edited by

JOHN F. LESLIE

Department of Plant Pathology

Kansas State University

Manhattan, Kansas, USA

ANTONIO F. LOGRIECO

Institute of Sciences of Food Production (ISPA)

National Research Council (CNR)

Bari, Italy

WILEY Blackwell

This edition first published 2014 © 2014 by John Wiley & Sons, Inc.

Editorial offices: 1606 Golden Aspen Drive, Suites 103 and 104, Ames, Iowa
50010, USA

The Atrium, Southern Gate, Chichester, West Sussex, PO19
8SQ, UK

9600 Garsington Road, Oxford, OX4 2DQ, UK

For details of our global editorial offices, for customer services and for information about how to apply for permission to reuse the copyrighted material in this book please see our website at www.wiley.com/wiley-blackwell.

Authorization to photocopy items for internal or personal use, or the internal or personal use of specific clients, is granted by Blackwell Publishing, provided that the base fee is paid directly to the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923. For those organizations that have been granted a photocopy license by CCC, a separate system of payments has been arranged. The fee codes for users of the Transactional Reporting Service are ISBN-13: 978-0-8138-2083-5/2014.

Designations used by companies to distinguish their products are often claimed as trademarks. All brand names and product names used in this book are trade names, service marks, trademarks or registered trademarks of their respective owners. The publisher is not associated with any product or vendor mentioned in this book.

Limit of Liability/Disclaimer of Warranty: While the publisher and author(s) have used their best efforts in preparing this book, they make no representations or warranties with respect to the accuracy or completeness of the contents of this book and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose. It is sold on the understanding that the publisher is not engaged in rendering professional services and neither the publisher, the editors, nor the authors shall be liable for damages arising herefrom. If professional advice or other expert assistance is required, the services of a competent professional should be sought.

Manuscript no. 14-068-B from the Kansas Agricultural Experiment Station,
Manhattan.

Library of Congress Cataloging-in-Publication Data has been applied for
ISBN 978-0-8138-2083-5

A catalogue record for this book is available from the British Library.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Cover image: iStockphoto © eyecrave

iStockphoto © MmeEmil

iStockphoto © ZoneCreative

Contents

[List of Contributors](#)

[Preface](#)

[Chapter 1 An Introduction to the MycoRed Project](#)

[Introduction](#)

[MycoRed Objectives](#)

[MycoRed Structure](#)

[Social and Economic Impact](#)

[Conclusions](#)

[References](#)

[Part I The Maize Grain Chain](#)

[Chapter 2 Identification of Toxigenic *Aspergillus* and *Fusarium* Species in the Maize Grain Chain](#)

[Introduction](#)

[Morphological Identification of Aflatoxin-Producing *A. flavus* and *A. parasiticus*](#)

[Morphological Identification of Toxin-Producing *Fusarium* Species](#)

[Cladal Relationship and Organization of the Toxin Biosynthetic Gene Cluster](#)

[Conclusions](#)

[Acknowledgments](#)

[References](#)

[Chapter 3 Determination of Mycotoxins in Maize](#)

[Introduction](#)

[Aflatoxin](#)

[Fumonisin](#)

[Discussion and Conclusions](#)

[References](#)

[Chapter 4 Breeding Maize for Resistance to Mycotoxins](#)

[Introduction](#)

[Techniques for Phenotyping Ear Rot and Mycotoxin Contamination](#)

[Sources and Genetics of Resistance](#)

[Traits Providing Resistance to Ear Rots](#)

[Genomic Resources for Analyzing *Fusarium* and *Aspergillus*-Maize Interactions](#)

[Transgenic Approaches to Reduce Ear Rots and Mycotoxin Accumulation](#)

[Future Prospects](#)

[References](#)

[Chapter 5 Crop Management Practices to Minimize the Risk of Mycotoxins Contamination in Temperate-Zone Maize](#)

[Introduction](#)

[Pre-planting Management Decisions](#)

[Post-planting Management Decisions](#)

[Integration of Risk Management Tactics](#)

[Risk Assessment or Prediction Modeling](#)

[Discussion](#)

[References](#)

[Chapter 6 Best Stored Maize Management Practices for the Prevention of Mycotoxin Contamination](#)

[Introduction](#)

[Fungal Source](#)

[Factors Affecting Fungal Growth and Mycotoxin Biosynthesis](#)

[Equilibrium Moisture Content of Maize](#)

[Common Fungi and Mycotoxins in Maize](#)

[Harvest Considerations](#)

[Maize Drying](#)

[Mechanical Damage, Broken Kernels, and Foreign Materials](#)

[Condensation](#)

[The SLAM Strategy](#)

[CO₂ Monitoring](#)

[Treating Mycotoxin-Contaminated Maize Grain](#)

[Conclusions](#)

[Acknowledgments](#)

[References](#)

[Chapter 7 Good Food-Processing Techniques: Stability of Mycotoxins in Processed Maize-Based Foods](#)

[Introduction](#)

[Mycotoxins](#)

[Effects of Food Processing](#)

[Conclusions](#)

[References](#)

[Chapter 8 Mycotoxin Reduction in Animal Diets](#)

[Introduction](#)

[Adsorption of Mycotoxins](#)

[Biological Detoxification](#)

[Conclusions](#)

[References](#)

Chapter 9 Physical and Chemical Methods for Mycotoxin Decontamination in Maize

Introduction

Physical Methods—Removal of Contaminated Materials

Physical Methods—Mycotoxin Inactivation

Physical Methods—Conclusions

Chemical Methods

Conclusions

Acknowledgments

References

Chapter 10 Aflatoxin B₁ Chemoprevention Strategies in Countries with Frequent Exposure to Mycotoxins

Introduction

Aflatoxins

Chemoprevention

Uptake Inhibitors

Summary

References

Part II The Wheat Grain Chain

Chapter 11 Identification of *Fusarium* spp. and *Penicillium verrucosum* in the Wheat Grain Chain

Introduction

The Problem of *Fusarium* and Its Toxins in Wheat: *Fusarium* Head Blight (FHB)

PCR Methods to Detect *Fusarium* in Wheat

New Detection Platforms

Conclusions and Future Perspectives

The Problem of *Penicillium* and Its Toxins in Wheat

[PCR Methods to Detect *P. verrucosum* in Wheat](#)

[RT-PCR Methods for Quantification and Monitoring of *P. verrucosum* in Wheat](#)

[The Application of Novel Platforms](#)

[Outlook](#)

[References](#)

[Chapter 12 Analytical Methods for Mycotoxins in the Wheat Chain](#)

[Introduction](#)

[Screening Methods for Mycotoxins in the Wheat Chain](#)

[Official Methods for Mycotoxins in the Wheat Chain](#)

[Research Methods for Mycotoxins in the Wheat Chain](#)

[Conclusions and/or Future Perspectives](#)

[References](#)

[Chapter 13 Breeding for Resistance to *Fusarium* Head Blight in Wheat](#)

[Introduction](#)

[Mycotoxins and Their Origin](#)

[The Wheat/*Fusarium* Breeding System](#)

[How Does a Breeding System Operate?](#)

[Summary and Outlook](#)

[References](#)

[Chapter 14 Good Agricultural and Harvest Practices to Reduce Mycotoxin Contamination in Wheat in Temperate Countries](#)

[Introduction](#)

[*Fusarium* Head Blight](#)

[Ergot](#)

[Pathogen-Free Seed](#)

[Fungicides](#)

[Crop Rotation and Residue Management](#)

[Irrigation](#)

[Delayed Harvest](#)

[Storage](#)

[Aflatoxins](#)

[Sterigmatocystin](#)

[Ochratoxins](#)

[Integrated Management to Reduce Losses from
Mycotoxigenic Fungi](#)

[Future Prospects](#)

[References](#)

[Chapter 15 Good Management Practices for
Minimizing the Risk of *Fusarium* Head Blight and
Mycotoxin Contamination in Nontraditional Warmer
Wheat-Growing Areas](#)

[Introduction](#)

[Nontraditional Warmer Growing Areas Where
Fusarium Head Blight Occurs](#)

[Guidelines for Minimizing the Risk of Mycotoxins
in Warmer Growing Areas: A Discussion](#)

[Conclusion](#)

[References](#)

[Chapter 16 Chemical Control of *Fusarium* Head
Blight of Wheat](#)

[Introduction](#)

[Factors Influencing Fungicide Effect](#)

[Inoculum](#)

[Variety Resistance—Host Plant Traits](#)

[Climatic Factors](#)

[Yield Potential](#)

[Fungicides](#)

[Management Inputs](#)

[Conclusions](#)

[References](#)

[Chapter 17 Predicting Mycotoxin Contamination in Wheat](#)

[Introduction](#)

[Why Try to Predict Mycotoxin Contamination in Wheat?](#)

[Using Visual Estimates of *Fusarium* Head Blight or *Fusarium* Head Blight Prediction Models to Predict Deoxynivalenol Contamination](#)

[Comparison of Models Used to Predict *Fusarium* Head Blight and Deoxynivalenol Accumulation](#)

[Application of Prediction Models](#)

[Challenges in Developing Mycotoxin Prediction Models](#)

[Challenges in the Application of Mycotoxin Prediction Models](#)

[The Future of Modeling Mycotoxins in Wheat](#)

[Conclusions](#)

[Acknowledgments](#)

[References](#)

[Chapter 18 Good Postharvest Storage Practices for Wheat Grain](#)

[Introduction](#)

[Moisture Sorption Curves](#)

[Risks of Deoxynivalenol Contamination during Grain Storage](#)

[Discussion and Conclusions](#)

[References](#)

[Part III Other Grain Chains](#)

[Chapter 19 Good Food and Feed Processing Techniques](#)

[Introduction](#)

[Aflatoxins](#)

[Ochratoxin A](#)

[Trichothecenes](#)

[Zearalenone](#)

[Patulin](#)

[Fumonisin](#)

[Moniliformin](#)

[Discussion](#)

[References](#)

[Chapter 20 Mycotoxins in the Sorghum Grain Chain](#)

[Introduction](#)

[Sorghum/Fungal Interactions](#)

[Reducing Mycotoxin Contamination](#)

[Particular Mycotoxins in Sorghum](#)

[Conclusions](#)

[Acknowledgments](#)

[References](#)

[Chapter 21 Toxigenic Fungi and Mycotoxins in the Rice Grain Chain and Strategies to Reduce Them](#)

[Introduction](#)

[Toxigenic Fungi in Rice](#)

[Occurrence of Mycotoxins in Rice](#)

[Detection and Analysis of Mycotoxins in Rice](#)

[Strategies to Reduce Mycotoxin Contamination in Rice](#)

[Conclusions](#)

[Acknowledgments](#)

[References](#)

[Chapter 22 Global Risk Maps for Mycotoxins in Wheat and Maize](#)

[Introduction](#)

[*Fusarium* Head Blight of Wheat](#)

[Mycotoxins in Maize](#)

[*Fusarium* Ear Rot of Maize](#)

[*Aspergillus* Ear Rot](#)

[Ecology and Modeling](#)

[Global Crop Distribution and Meteorological Conditions](#)

[Global Risk Maps for Mycotoxins in Wheat and Maize](#)

[Risk Maps for Mycotoxins in Wheat and Maize](#)

[Closing Comments](#)

[Acknowledgments](#)

[References](#)

[Index](#)

[End User License Agreement](#)

List of Tables

[Chapter 1](#)

Table 1.1

Chapter 4

Table 4.1

Chapter 5

Table 5.1

Table 5.2

Chapter 6

Table 6.1

Table 6.2

Table 6.3

Chapter 7

Table 7.1

Chapter 9

Table 9.1

Chapter 10

Table 10.1

Chapter 11

Table 11.1

Chapter 12

Table 12.1

Table 12.2

Table 12.3

Table 12.4

Chapter 13

Table 13.1

[Chapter 14](#)

[**Table 14.1**](#)

[Chapter 15](#)

[**Table 15.1**](#)

[Chapter 16](#)

[**Table 16.1**](#)

[**Table 16.2**](#)

[**Table 16.3**](#)

[**Table 16.4**](#)

[Chapter 17](#)

[**Table 17.1**](#)

[Chapter 20](#)

[**Table 20.1**](#)

[**Table 20.2**](#)

[Chapter 21](#)

[**Table 21.1**](#)

[**Table 21.2**](#)

[Chapter 22](#)

[**Table 22.1**](#)

[**Table 22.2**](#)

[**Table 22.3**](#)

[**Table 22.4**](#)

List of Illustrations

[Chapter 1](#)

Figure 1.1 MycoRed stakeholders. The size of the circle indicates the relative importance of the user group. The relative distance of the circle to the user group indicates the relative strength of the communication with that group, with shorter lines indicating stronger communications than longer ones.

Chapter 2

Figure 2.1 Basic morphological structure of *Aspergillus* showing (i) biseriate and (ii) uniseriate conidial heads.

Figure 2.2 Scanning electron micrograph of conidia for *Aspergillus flavus* (left panels a and b) and *Aspergillus parasiticus* (right panels c and d).

Figure 2.3 Spore morphology characters used in the identification of *Fusarium* species. Drawings are idealized and not necessarily to the same scale. (a-d) Macroconidial shapes. (a) Typical *Fusarium* macroconidium. Apical cell on left, basal cell on right. (b) Slender, straight, almost needle-like macroconidium, e.g., *F. avenaceum*. (c) Macroconidium with dorsoventral curvature, e.g., *F. equiseti*. (d) Macroconidium with the dorsal side more curved than the ventral, e.g., *F. crookwellense*. (e-h) Macroconidial apical cell shapes. (e) Blunt, e.g., *F. culmorum*. (f) Papillate, e.g., *F. sambucinum*. (g) Hooked, e.g., *F. lateritium*. (h) Tapering, e.g., *F. equiseti*. (i-l) Macroconidial basal cell shapes. (i) Foot shaped, e.g., *F. crookwellense*. (j) Elongated foot shape, e.g., *F. longipes*. (k) Distinctly notched, e.g., *F. avenaceum*. (l) Barely notched, e.g., *F. solani*. (m-t) Microconidial spore shapes. (m) Oval. (n) Two-celled oval. (o) Three-celled oval. (p) Reniform. (q) Obovoid with a truncate base. (r) Pyriform. (s) Napiform. (t)

Globose. (u-x) Phialide morphology. (u) Monophialides, e.g., *F. solani*. (v) Monophialides, e.g., *F. oxysporum*. (w) Polyphialides, e.g., *F. polyphialidicum*. (x) Polyphialides, e.g., *F. semitectum*. (y-z) Microconidial chains. (y) Short chains, e.g., *F. nygamai*. (z) Long chains, e.g., *F. verticillioides*. From Leslie and Summerell (2006); used with permission.

Chapter 5

Figure 5.1 Effects of maize hybrid and planting date on populations of thrips in maize ears, 21 days after pollination (top). Fumonisin B₁ concentrations in maize kernels after harvest (middle). Percentage of kernels with *Fusarium* ear rot symptoms at harvest (bottom) in a field experiment conducted for 2 years in California, USA. Hybrids A, B, and C were commercial dent maize hybrids that vary in husk coverage and susceptibility to *Fusarium* ear rot. Planting dates were late March, late April, or late May. Data from Parsons and Munkvold (2010).

Figure 5.2 European corn borer (ECB) incidence and severity, fumonisin concentrations, and grain yields from three crop management programs compared in field trials at three locations over 2 years in northwest Italy. Treatment 1: May planting, 80,000 plants/ha, 400 kg nitrogen fertilization/ha, no insecticide; Treatment 2: late March to early April planting, 80,000 plants/ha, 400 kg nitrogen fertilization/ha, no insecticide; Treatment 3: late March to early April planting, 65,000 plants/ha, 200 kg nitrogen fertilization/ha, no insecticide; Treatment 4: late March to early April planting, 65,000 plants/ha, 200 kg nitrogen fertilization/ha, insecticide treated for control of ECB. Data from Blandino *et al.* (2009a).

Figure 5.3 Variation in deoxynivalenol concentration attributable to year, maize hybrid, and previous crop in grain from commercial fields in Ontario, Canada, from 1993 to 1999. *indicates statistically significant effects ($p \leq 0.05$). Data from Hooker and Schaafsma (2005).

Chapter 6

Figure 6.1 Equilibrium moisture content relationship for shelled corn at various temperatures and relative humidities.

Chapter 7

Figure 7.1 Chemical structures of the most important mycotoxins.

Chapter 10

Figure 10.1 Simplified overview of important steps and key metabolites in the established metabolic pathways for aflatoxin B₁ (AFB₁) and biomarkers used to assess the efficacy of aflatoxin intervention studies [modified from Turner *et al.*, 2012]. This set of metabolites and enzymes excludes many other pathways and is simplified here to focus on those important in understanding chemoprevention. AFM₁, aflatoxin M₁. (For a color version, see the color plate section.)

Chapter 11

Figure 11.1 Risk map of ochratoxin biosynthesis by *Penicillium* based on expression data.

Chapter 13

Figure 13.1 Aggressiveness (diseased germs %) and conidium concentration ($\times 10^4$) of inocula of *F. culmorum* isolate 12551. *Aggressiveness:

percentage of healthy germs across two cultivars, five recording times (2-6 days after inoculation), and four concentrations (original and diluted 1:1, 1:2, and 1:4 with distilled water; Mesterházy, 1985).

Figure 13.2 Deoxynivalenol (DON) and *Fusarium* diseased kernels (FDK) values of Western European, Hungarian cultivars and highly resistant varieties and lines from the Szeged breeding program. Data are means across four environments and 2 years.

Figure 13.3 Regression between *Fusarium* damaged kernels (FDK) and deoxynivalenol (DON) contamination, 2006, $n = 139$. Data represent means across four isolates with different aggressiveness.

Chapter 16

Figure 16.1 *Fusarium*-diseased kernels values from a susceptibility window test in 1992. Inoculation of fungicide-treated plots followed 2 days after fungicide treatment and 10 days later. Fungicide rates: Tilt: 1.0, Kolfugo 1.5, Fol. BT 2.0, Fol. BT 1.0, and Fol. 250 1.0 L/ha. Composition of the fungicides is given in Table 16.3

Figure 16.2 Comparison of nozzle types on fungicide protection against *Fusarium* head blight in wheat in 2007 in a large-scale field application, 21 days after application. Data: means across three wheat cultivars and number of infected heads as a percentage of the non-protected control.

Chapter 17

Figure 17.1 Conceptual diagram of the similarities in factors influencing the development of *Fusarium* head blight caused by *Fusarium graminearum* and the resulting contamination of the grain with the mycotoxin deoxynivalenol. Although similar factors

result in disease development and mycotoxin accumulation (symbolized by the overlapping triangles), important differences in these complex relationships among host plants, pathogens, and the environment may affect the disease and toxin differentially (offsetting the triangles), making it difficult to reliably predict the risk of deoxynivalenol contamination based on actual estimates of *Fusarium* head blight or with models developed to predict *Fusarium* head blight.

Figure 17.2 Prediction models for *Fusarium* head blight of wheat caused by *Fusarium graminearum* are available for public use via the Internet (www.wheatcab.psu.edu). The user interface displays daily estimates of disease risk for 30 states east of the Rocky Mountains in the United States. The prediction models deployed through the site were developed through the collaboration of researchers at Kansas State University, the Pennsylvania State University, and the Ohio State University. This interface for the model was designed by the Center of Environmental Informatics at the Pennsylvania State University.

Chapter 18

Figure 18.1 Moisture sorption curve for wheat grain relating the adsorption and desorption curves to moisture content (% wet weight basis). The adsorption lines indicate the effect of wetting grain and the desorption lines indicate the effect of wet grain being dried. The difference is due to the relative binding of water to the grain components during these phases and is called the “hysteresis effect.” These curves change with storage temperature. In general, spoilage problems normally

would not occur below the conditions indicated by the arrow ($\sim 14.5\%$ moisture content = $0.70 a_w$).

Figure 18.2 Comparison of profiles for (a) growth (mm/day) and (b) deoxynivalenol ($\mu\text{g/g}$) production by *Fusarium graminearum* on wheat grain (after Magan *et al.*, 2006).

Figure 18.3 Profiles for (a) relative growth rates (mm/day) and (b) ochratoxin A ($\mu\text{g/g}$) production by *Penicillium verrucosum* on wheat grain. The lines are isopleths at which similar amounts of growth or ochratoxin A production occur (after Cairns-Fuller *et al.*, 2005).

Figure 18.4 The relationship between temperature and moisture content of grain and the length of time for which the grain can be stored.

Figure 18.5 Ranges for deoxynivalenol (DON) and ochratoxin A (OTA) contamination and the zone of “uncertainty” where conducive conditions exist for increased contamination by ochratoxin A.

Chapter 22

Figure 22.1 (a) Global risk of deoxynivalenol contamination in wheat. The prediction is based on monthly data for mean temperature and rain occurring near heading. (b) Global risk of fumonisin contamination in maize. The prediction is based on monthly data for mean temperature and rain occurring near silk emergence. (c) Global risk of aflatoxin B₁ contamination in maize. The prediction is based on the aridity index during heading and ear ripening.

List of Contributors

David Aldred

Applied Mycology Group
Cranfield Health
Cranfield University
Bedford, UK
e-mail: d.aldred@cranfield.ac.uk

Paola Battilani

Institute of Entomology and Plant Pathology
Università Cattolica del Sacro Cuore
Piacenza, Italy
e-mail: paola.battilani@unicatt.it

Esther S. Baxter

Applied Mycology Group
Cranfield Health
Cranfield University
Bedford, UK
e-mail: e.baxter@cranfield.ac.uk

G rard Bertin

Erawan Consulting SARL
Asni res-sur-Seine, France
e-mail: erawan.consulting@gmail.com

Deepak Bhatnagar

Food and Feed Safety Research
Southern Regional Research Center
USDA-ARS
New Orleans, Louisiana, USA
e-mail: deepak.bhatnagar@ars.usda.gov

Andreia Bianchini

Department of Food Science and Technology
University of Nebraska-Lincoln

Lincoln, Nebraska, USA
e-mail: abianchini2@unl.edu

Lloyd B. Bullerman

Department of Food Science and Technology
University of Nebraska-Lincoln
Lincoln, Nebraska, USA
e-mail: lbullerman1@unl.edu

Lakshmi Kantha H. Channaiah

Department of Grain Science and Industry
Kansas State University
Manhattan, Kansas, USA
e-mail: kantha@ksu.edu

Erick de Wolf

Department of Plant Pathology
Kansas State University
Manhattan, Kansas, USA
e-mail: dewolf1@ksu.edu

Etienne Duveiller

Global Wheat Program
Centro Internacional de Mejoramiento de Maiz y Trigo
Mexico
e-mail: e.duveiller@cgiar.org

Rolf Geisen

Molecular Food Mycology
Max Rubner Institut
Federal Research Institute for Nutrition and Food
Karlsruhe, Germany
e-mail: rolf.geisen@mri.bund.de

John Gilbert

FoodLife International Ltd
Ankara, Turkey
e-mail: john.gilbert@foodlifeint.com

Bertrand Grenier

Institut National de la Recherche Agronomique
INRA UR66
Laboratoire de Pharmacologie-Toxicologie
Toulouse Cedex, France
e-mail: bertrand.grenier@toulouse.inra.fr

Farhana Nazira Idris

School of Biological Sciences
Universiti Sains Malaysia
Penang, Malaysia
e-mail: farhana_nazira@yahoo.com

Barry Jacobsen

Department of Plant Sciences and Plant Pathology
Montana State University
Bozeman, Montana, USA
e-mail: uplbj@montana.edu

Didier Jans

FEFANA (EU Association of Specialty Feed Ingredients
and
their mixtures)
Brussels, Belgium
e-mail: dja@fefana.org

Maren Klich

Food and Feed Safety Research
Southern Regional Research Center
USDA-ARS
New Orleans, Louisiana, USA

Alessandra Lanubile

Institute of Agronomy, Genetics and Field Crops
Università Cattolica del Sacro Cuore
Piacenza, Italy
e-mail: alessandra.lanubile@unicatt.it

Yin-Won Lee

Center for Fungal Pathogenesis
Department of Plant Microbiology

Faculty of Agriculture and Life Sciences
Seoul National University
Seoul, Korea
e-mail: lee2443@snu.ac.kr

Anne Legrève

Unité de Phytopathologie
Université Catholique de Louvain
Louvain-la-Neuve, Belgium
e-mail: anne.legreve@uclouvain.be

John F. Leslie

Department of Plant Pathology
Kansas State University
Manhattan, Kansas, USA
e-mail: jfl@ksu.edu

Antonio F. Logrieco

Institute of Sciences of Food Production (ISPA)
National Research Council (CNR)
Bari, Italy
e-mail: antonio.logrieco@ispa.cnr.it

Ana-Paula Loureiro-Bracarense

Laboratorio Patologia Animal
Universidade Estadual de Londrina
Londrina, Brazil
e-mail: anauel02@yahoo.com.br

Naresh Magan

Applied Mycology Group
Cranfield Health
Cranfield University
Bedford, UK
e-mail: n.magan@cranfield.ac.uk

Dirk E. Maier

Department of Grain Science and Industry
Kansas State University

Manhattan, Kansas, USA
e-mail: dmaier@ksu.edu

Adriano Marocco

Institute of Agronomy, Genetics and Field Crops
Università Cattolica del Sacro Cuore
Piacenza, Italy
e-mail: adriano.marocco@unicatt.it

Valentina Maschietto

Institute of Agronomy, Genetics and Field Crops
Universita Cattolica del Sacro Cuore
Piacenza, Italy

Ákos Mesterházy

Division of Wheat Breeding
Cereal Research Non-Profit Company
Szeged, Hungary
e-mail: akos.mesterhazy@gk-szeged.hu

Monica Mezzalama

Global Wheat Program
Centro Internacional de Mejoramiento de Maiz y Trigo
Mexico
e-mail: m.mezzalama@cgiar.org

Antonio Moretti

Institute of Sciences of Food Production (ISPA)
National Research Council (CNR)
Bari, Italy
e-mail: antonio.moretti@ispa.cnr.it

Gary Munkvold

Department of Plant Pathology
Iowa State University
Ames, Iowa, USA
e-mail: munkvold@iastate.edu

Isabelle P. Oswald

Institut National de la Recherche Agronomique
INRA UR66

Laboratoire de Pharmacologie-Toxicologie
Toulouse Cedex, France
e-mail: ioswald@toulouse.inra.fr

Michelangelo Pascale

Institute of Sciences of Food Production (ISPA)
National Research Council (CNR)
Bari, Italy
e-mail: michelangelo.pascale@ispa.cnr.it

Pierce A. Paul

Department of Plant Pathology
Ohio Agricultural Research and Development Center
Ohio State University
Wooster, Ohio, USA
e-mail: paul.661@osu.edu

Gary Payne

Department of Plant Pathology
North Carolina State University
Raleigh, North Carolina, USA
e-mail: gary_payne@ncsu.edu

Katia Pedrosa

Biomin Holding GmbH
Herzogenburg, Austria
e-mail: katia.pedrosa@biomin.net

Assunta Raiola

Department of Food Science
Università degli Studi di Napoli Federico II
Portici, Italy
e-mail: assuntaraiola@hotmail.com

Alberto Ritieni

Department of Food Science
Università degli Studi di Napoli Federico II
Portici, Italy
e-mail: alberto.ritieni@unina.it

Bahrudin Saad

School of Chemical Sciences
Universiti Sains Malaysia
Penang, Malaysia
e-mail: bahrud@usm.my

Baharuddin bin Salleh

School of Biological Sciences
Universiti Sains Malaysia
Penang, Malaysia
e-mail: sallehb@usm.my

Dian Schatzmayr

Biomin Research Center
Tulln, Austria
e-mail: dian.schatzmayr@biomin.net

Gordon S. Shephard

PROMEC Unit
Medical Research Council
Tygerberg, South Africa and
Cape Peninsula University of Technology
Bellville, South Africa
e-mail: gordon.shephard@mrc.ac.za

Paul C. Turner

Maryland Institute for Applied and Environmental
Health
School of Public Health Building
University of Maryland
College Park, Maryland, USA
e-mail: pturner3@umd.edu

Angelo Visconti

Institute of Sciences of Food Production (ISPA)
National Research Council (CNR)
Bari, Italy
e-mail: angelo.visconti@ispa.cnr.it

Cees Waalwijk

Biointeractions and Plant Health
Plant Research International B.V.
Wageningen, The Netherlands
e-mail: cees.waalwijk@wur.nl