From Science to Field
Maize Case Study – Guide Number 3

Prevention Of Ear Rots Due To *Fusarium* Spp. On Maize And Mycotoxin Accumulation

Elzbieta Czembor, Plant Breeding and Acclimatization Institute, Radzikow, Poland; Jozef Adamczyk, Plant Breeding Smolice Ltd., Kobylin, Poland; Katalin Posta, Plant Protection Institute, Szent István University, Gödöllö, Hungary; Elisabeth Oldenburg, Julius Kühn Institute, Braunschweig, Germany; Stephanie Schürch, Agroscope ACW Changins-Wädenswil, Switzerland

endure
diversifying crop protection

Food Quality and Safety
6TH FRAMEWORK PROGRAMME

Prevention Of Ear Rots Due To *Fusarium* Spp. On Maize And Mycotoxin Accumulation

Ear rots in Europe

Despite the fact that more than 95% of the maize seeds planted in Europe every year are treated with fungicides, disease problems continue to develop in many fields affecting both the yield and quality of the grain crop. *Fusarium* spp. causing ear rots are the most economically significant diseases in most European regions and, with the exception of Spain, are an increasing problem in Europe.

The biology and distribution of *Fusarium* species

The major maize fungal diseases can be grouped into four categories: leaf blights, stalk rots, and ear and kernel rots. Ear and kernel rots decrease yield, quality and the feed value of the grain. The most important diseases are red ear rot (or Gibberella ear rot) and pink ear rot (also called *Fusarium* ear rot). Red ear rot is caused by *Fusarium graminearum* and *F. culmorum*, whereas pink ear rot is caused by *F. verticillioides*, *F. proliferatum* and *F. subglutinans*.

At least 15 other *Fusarium* species may be found on maize ears, each producing a different array of mycotoxins. In red ear rot, infection starts at the tip of the ear just after female flowering and moves toward the base. Typically the husks are also infected and fuse with the ear. In pink ear rot, infection tends to be more uniform, with no real concentration at the tip.

Above: Despite fungicide treatments maize ears remain vulnerable to disease. © Elzbieta Czembor, IHAR, Poland. Below: European corn borer larvae not only cause physical damage to stalks and ears, but promote infections by Fusarium spp. © Gabriela Brändle, Agroscope ART, Switzerland.

Impact of corn borer on pink ear rot

There is often a high correlation between symptoms of pink ear rot and ear damage caused by European corn borer larvae (*Ostrinia nubilalis* Hbn.). Larvae cause physical injuries to stalks and ears, and promote infections by *Fusarium* spp. in two ways. Firstly, European corn borer larvae can carry spores of *Fusarium* species from the plant surface to the surfaces of damaged kernels or to the interior of stalks, where infection occurs. Viable spores can be found externally, internally and in the frass of European corn borer larvae. Secondly, these larvae form entry wounds when feeding on stalks or kernels. Even when larvae do not directly carry fungi into the stalks, spores subsequently deposited on wounded tissue are very likely to germinate and infect the plant. It should be noted, though, that there is some disagreement among plant pathologists about the overall importance of insect tunnelling on stalk rot development.

Below: Red ear rot infection starts at the tip of the ear, just after female flowering. © Elzbieta Czembor, IHAR, Poland. Right: Evidence of European corn borer activity and subsequent symptoms of pink ear rot. © Stephanie Schürch, Agroscope ACW Changins-Wädenswil, Switzerland.

Mycotoxin accumulation in food and feed and health effects

Infection by *Fusarium* spp. results not only in yield reduction but also in contamination with mycotoxins. The main mycotoxins produced by *F. graminearum* are deoxynivalenol (DON), nivalenol (NIV) and zearalenone (ZEA), whereas *F. verticillioides* produces mainly fumonisins (FUM) B_1 and B_2 and moniliformin (MON). Mycotoxins are resistant to high temperatures and chemicals. They can accumulate in grain, heavily contaminate grain-based food and feed, and can cause many diseases.

For animal feed, guidance values vary between 2,000 and 8,000 µg kg^{-1} for DON and FUM and 250-500 µg kg^{-1} for ZEA depending on the feed stuff and animal species. At concentrations of about 2,000 µg kg^{-1} of feed, DON decreases feed intake and reduces weight gain of pigs. T-2 and HT-2 toxin are more toxic than DON and cause reduction of feed intake, vomiting, irritation of the skin, neurotoxicity, teratogenicity, impaired immune function and haemorrhage. Adverse effects seen in farm animals are generally caused by toxin mixtures rather than by single toxins. Zearalenone shos oestrogen-like activity and may cause infertility and abortion in livestock, especially swine. Fumonisin B_1 has cancer-promoting activity in rats, causes equine leukoencephalomalacia, and is associated with porcine pulmonary oedema.

Levels of *Fusarium* mycotoxins in maize for human consumption are listed below in Table 1.

Table 1: Maximum levels of *Fusarium* mycotoxins in maize for human consumption (Commission regulation (EC) No 1126/2007)

Product	Deoxynivalenol (DON) [µg/kg]	Zearalenone (ZEA) [µg/kg]	Fumonisins (FUM B_1 + FUM B_2) [µg/kg]
Unprocessed maize with the exception of unprocessed maize intended to be processed by wet milling	1,750	350	4,000
Maize intended for direct human consumption	780	100	1,000
Maize-based snacks and maize-based breakfast cereals	500	100	800
Processed cereal-based foods and baby foods for infants and young children	200	20	200

Milling fractions of maize with particle size >500 micron falling within CN code 1103 13 or 1103 20 40 and other maize milling products with particle size >500 micron not used for direct human consumption	750	200	1,400
Milling fractions of maize with particle size ≤500 micron falling within CN code 1102 20 and other maize milling products with particle size ≤500 micron not used for direct human consumption	1,250	300	2,000
Refined maize oil		400	

Preventive control of ear rots

As no efficient chemical control in the field is possible, prevention relies on cultural practices to manage diseases.

Crop rotation: The main inoculum source for red and pink ear rots of maize are crop residues of previous diseased crops. The best documented example is the high risk of ear rot when maize is grown in monoculture or after wheat. Maize stubble is often colonised by the same *Fusarium* spp. as the ones affecting wheat and these *Fusarium* spp. can survive and multiply on maize stubble for several years.

Crop residue management: Three removal methods are recommended, involving physical removal or the use of specially designed biological crop residue treatments. Microbial decomposition of crop residues is a natural process which can be supported by adding stimulating nutrients or selected micro-organisms. Using a cultivator it is possible to mix mulched maize residues into the ground to accelerate decomposition. Mechanical cutting of plant residues before ploughing is recommended to minimise infection and to promote rotting.

Good nutrient supply for the plants: Maize plants can be predisposed to *Fusarium* infection by high levels of nitrogen and low levels of potassium.

Varietal choice: One important prevention measure to control red and pink ear rots is to use resistant hybrids. Two types of ear rot resistance have been identified in maize. Silk channel resistance prevents the fungus from invading through the silk channel down to the kernels. Kernel resistance blocks the spread of the fungus from kernel to kernel. Resistance to *Fusarium* spp. is quantitatively inherited, but until now no fully resistant maize genotype has been discovered. The relationships between resistance and mycotoxin contamination have been documented. Hybrids that hold their ears vertically and have poor ear cover can be more susceptible to pink ear rot. Hybrids with tight husks appear to be more vulnerable to red ear rot.

Seed quality: Seeds have a small effect on red and pink ear rots. However, they should be of the best quality and free of diseases and pests to guarantee the highest production potential.

Sowing time: Early plantings usually escape serious injury.

Crop structure: High plant density affects the development of disease and, indeed, increases the risk of disease through increased humidity in the canopy. Infection by *Fusarium* spp. and disease development are favoured by warm conditions and moist periods.

Harvest time and storage: Late harvest is a major risk factor. It is therefore important to grow varieties belonging to a precocity group adapted to the local climatic conditions. After harvest, the disease can continue its development if ears are stored in conditions of high humidity and insufficient aeration. This means harvested grain should be dried to 15% moisture content or below to prevent mould growth in storage. Good storage conditions such as an appropriate temperature and moisture content, aeration, insect control and clean bins will lower significantly the risk of grain infection.

Table 2: Tentative ranking of management options and their impact on ear rot diseases

Management factors	Impact on ear rot reduction
Preventive control	
Crop rotation	High
Crop residue management	High
Harvest time and storage	High
Good nutrient supply	Medium
Varietal choice	Medium
Seed quality	Low
Sowing time	Low
Crop structure	Low

Direct control	
Insect control	High
Weed control	Low
Chemical disease control	Low

Direct control

Chemical disease control: In the case of systemic infections of maize plants with *Fusarium* spp., application of fungicide early in the season can limit ear infection. When pink or red ear rot diseases develop late in the season, the use of fungicides is not appropriate. If the *Fusarium* spp. has already attacked maize plants, harvesting should be completed as soon as possible.

Weed control: Control of weeds has a low effect on pink and red ear rot reduction. However, weeds can affect the development of the disease if they offer more favourable conditions for the development of *Fusarium* spp., for example, higher humidity in the crop.

Insect management: Control of insect pests will reduce infection of *Fusarium* spp. For example, arthropod pests often transmit viruses causing stress for plants, and feeding wounds facilitate infection by pathogens such as *Fusarium* spp. European corn borer larvae carry spores of *Fusarium* species from the plant surface to the surfaces of damaged kernels or to the interior of stalks, where infection occurs. Maize cultivars carrying the *Bt* gene are highly resistant to European corn borer larval feeding. In addition, maize hybrids expressing the *Bt* gene have been found to be less infected with *Fusarium* spp. and showed lower mycotoxin concentrations in kernels.

Acknowledgements

The following institutions are acknowledged for their contribution to ENDURE's Maize Case Study, 'Key pests and options to reduce pesticides in eleven European regions': Agroscope Reckenholz-Tänikon Research Station ART (Switzerland); Universitat de Lleida (Spain); Biotop (France); ARVALIS - Institut du Végétal (France); University of Aarhus (Denmark); The National Centre - Danish Agricultural Advisory Service (Denmark); National Research Council CNR (Italy); Scuola Superiore Sant'Anna di Pisa (Italy); International Biocontrol Manufacturers Association, IBMA; Plant Breeding and Acclimatization Institute IHAR (Poland); Julius Kühn-Institut - Federal Research Centre for Cultivated Plants (Germany); Szent István University (Hungary); Wageningen University and Research Centre (The Netherlands); Applied Plant Research, Wageningen UR (The Netherlands).

Prevention Of Ear Rots Due To *Fusarium* Spp. On Maize And Mycotoxin Accumulation

Summary

Red and pink ear rot diseases caused by *Fusarium* spp. occur widely throughout the maize growing regions of the world. Infection appears on the surface of ears at the end of the milky stage or at the beginning of the waxy stage. If the mould is thick, the grains are destroyed.

Fusarium spp. produce mycotoxins. The most important are deoxynivalenol, nivalenol, zearalenone, fumonisins and moniliformin. They cause immuno-suppression, embryo abortions and deformations, swine enderogenic syndrome, porcine pulmonary oedema, liver cancer in rats and oesophageal cancer in humans.

Crop rotation, crop residue management, varietal choice (including *Bt* maize) and good storage have the highest impact on disease severity and on mycotoxin contamination.

For further information please contact:

Elzbieta Czembor, Plant Breeding and Acclimatization Institute (IHAR), Radzkow, 05-870 Blonie, Poland.
E-mail: e.czembor@ihar.edu.pl

Franz Bigler, Agroscope Reckenholz-Tänikon Research Station ART, Reckenholzstrasse 191, 8046 Zurich, Switzerland. Tel: (+41) 443777235. E-mail: franz.bigler@art.admin.ch

About ENDURE

ENDURE is the European Network for the Durable Exploitation of Crop Protection Strategies. ENDURE is a Network of Excellence (NoE) with two key objectives: restructuring European research and development on the use of plant protection products, and establishing ENDURE as a world leader in the development and implementation of sustainable pest control strategies through:

> Building a lasting crop protection research community
> Providing end-users with a broader range of short-term solutions
> Developing a holistic approach to sustainable pest management
> Taking stock of and informing plant protection policy changes.

Eighteen organisations in 10 European countries are committed to ENDURE for four years (2007-2010), with financial support from the European Commission's Sixth Framework Programme, priority 5: Food Quality and Security.

Website and ENDURE Information Centre:

www.endure-network.eu

This publication was funded by EU grant (Project number: 031499), under the Sixth Framework Programme, and is catalogued as ENDURE Maize Case Study – Guide Number 3, published in June, 2010.