# WINDS OF CHANGE

## An emergent threat with Climate Change

It is no news that Climate Change will have severe consequences in many aspects of our lives. Global warming, local temperature increases, heavy rainfall, droughts, floods, and extreme weather events are constantly reported and discussed. It is not surprising that agriculture will also be impacted by these changes, affecting productivity, soil and water resources, the resilience of plants, and the emergence of new pests and diseases.

*Alternaria* in apple, orange, tangerine, lemon, bell pepper, blueberry, walnut and cereal grains.

Plant diseases are particularly affected by Climate Change since it alters pathogens evolution and modifies the scenario in which the interaction plant-pathogen takes place. The new set of conditions might enhance the plant vulnerability to pre-existing members of the microbiome that have not represented a risk before. Furthermore, pathogens move to previously uncharted, warmer regions, expanding their geographical reach and introducing diseases to areas where they were previously absent.

Fungal pathogens are among the most common causal agents of crop diseases. Their harmful effects result in significant economic losses related to lower yield, crop management and prevention strategies. An additional adverse outcome manifests when the pathogen in question can synthesise mycotoxins, toxic secondary metabolites that can accumulate in edible parts of the plant and render the crop unfit for commercialisation. Several of these mycotoxins are regulated by food safety authorities, such as the FSA in the UK, EFSA in the EU or FDA in the USA, and the limits allowed are usually exceptionally low (ppb, parts per billion).

Besides regulated mycotoxins, a new term, **"emerging mycotoxins"** is becoming trending topic in the scientific community. And Climate Change has a relevant role in making these metabolites suddenly "emerge" and become the target of research and reports.

**A typical example is the fungus *Alternaria*,** an emerging pathogen producing a myriad of secondary metabolites, many of which are declared mycotoxins. Alternaria has been described as a common plant pathogen in a wide range of crops. It is the causal agent of several diseases in fruits and vegetables, infecting plants in the field, but also spreading the disease in postharvest storage. There are hundreds of different species of this fungal genus, each one with their own characteristics in terms of host adaptation, environment, and capacity to produce mycotoxins. Moreover, different species can infect respective parts of the plant, causing leaves blight, stem canker, fruit or tuber rot, depending on their virulence mechanism. And to complicate the scenario even more, not all of them can produce mycotoxins, meaning that fruit rot or grain discoloration do not necessarily implies the presence of these toxic metabolites. But the contrary is also true; healthy fruits or kernels are not exempt from mycotoxin contamination. These toxins pose a challenge not just for primary producers as they remain impervious to heat-based treatments applied during food processing once they have formed in the fruit or grain.

## Where can we find *Alternaria*?

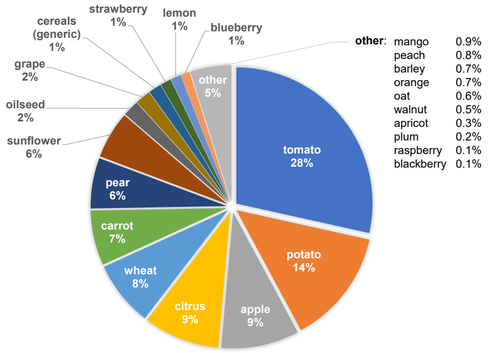
The list of food crops in which *Alternaria* or its toxins have been detected is long. It is frequent in **fruits and vegetables**, but it can also infect **cereal grains, oilseeds and nuts**, causing visible damage or with undetectable traits, but always posing the risk of mycotoxin contamination in the apparently healthy food.

## Where does Climate Change intervene in the incidence of *Alternaria*?

The most frequent reports on *Alternaria* in crops originate from subtropical climate regions, such as Mediterranean countries, Southern USA, Northern Mexico, South America and Southern Asia. The climate is not only adequate for the host crops, but perfectly suits the pathogen, and warmer temperatures with alternate cycles of humid-dry conditions are especially favourable for the toxigenic species over non-toxigenic ones. However, Climate Change has the double effect of sweeping the pathogen from subtropical to temperate climate regions that are becoming warmer as well as replacing the pre-existing local *Alternaria* species by the more aggressive, mycotoxin-producing ones.

We already see it happening in **potato** crops in the UK, where, from being a minor disease, *Alternaria* is currently becoming a major menace. The co-occurrence of different species, with their own characteristics of virulence and resistance, renders the management of the disease a more challenging venture. The delicate balance between *A. solani*, the main causal agent of early blight, and other species is tipping towards the ubiquitous *A. alternata*. The latter, fast grower at high temperatures and dry conditions, is likely to infect earlier, especially if the plant resistance has been reduced under stress conditions. *A. alternata*, as opposed to *A. solani*, is a strong mycotoxin producer; however, no reports have shown their accumulation in the tuber so far. Nonetheless, a timing control strategy is required to prevent the damage caused by this pathogen.

In cereals such as wheat, barley and oats, the *Alternaria* species are also unevenly distributed depending on the geographical region and climatic conditions. When considering mycotoxin-producing fungi causing losses in cereals, the biggest threat is historically associated with Fusarium species. Deoxynivalenol, zearalenone, T-2 and HT-2, are toxins from different Fusarium species that can become predominant depending on the crop and weather conditions. However, Climate Change has started altering the dynamics between *Fusarium* and *Alternaria* species. For example, wheat grown in subtropical climate countries, in which Fusarium Head Blight has been the foremost disease to prevent, is starting to show increasing *Alternaria* infection, and its mycotoxins can be detected at high levels, particularly when experiencing warm and dry conditions during flowering. In Northern Europe, *A. infectoria* and related species were the predominant in cereals, with less aggressive characteristics than *A. alternata* and inability to produce the main *Alternaria* toxins.




Distribution of reports on *Alternaria* for different crops

Search on scientific reports on Scopus with the word *Alternaria* in the title and the respective crop. The percentages were calculated over the total number of reports with the word *Alternaria* in the title by October 2023.

It is expected, however, that Climate Change conveys a shift towards the latter, when warm and dry episodes occur near flowering. The pathogen dispersal can also be favoured by climatic conditions: high levels of *Alternaria* spores have been detected in the air in cereals and oilseed rape areas in the UK, meaning that dry weather during harvesting would be ideal for the wind to disperse the spores in neighbouring fields and even more distant places. On the other hand, the toxigenic species are becoming prevalent in wheat and oats under extreme weather events, such as the high summer temperatures in 2022. Thus, monitoring cereals for *Alternaria* toxins would be a preventive measure for future seasons.

## Which processed foods are at risk?

*Alternaria* is one of the most common pathogens of **tomatoes**, especially processing fruits grown in the field.

*Alternaria* black mould on tomato fruits

Tomato plants can be affected by different *Alternaria* species causing early blight (*A. solani*), stem canker (*A. arborescens*) and black mould fruit rot (*A. alternata*, *A. arborescens*). The fruit disease can proliferate in postharvest, and, as the causal agents are mycotoxin producers, the toxic metabolite levels increase in this period. When the fruits are processed to produce canned tomatoes, sauces, ketchup, or soups, *Alternaria* toxins are not destroyed, and their levels rise as the product is concentrated. It is expected that the more aggressive and toxigenic species become predominant in the future, replacing other non-toxigenic pathogens, a fact already raising concern in the tomato products industry. EFSA has recently recommended monitoring *Alternaria* toxins in selected food, from which tomato products is at the core.

Although EFSA's recommendations have not included them, processed fruit products are frequently contaminated with *Alternaria* toxins. Fruit juices have shown relatively low levels of these mycotoxins, but **of particular concern are fruit products intended for infants and toddlers**, such as purees, nectars and baby food. Apples are particularly susceptible to *Alternaria* infection; it can cause leaf blotch, fruit spot and mouldy core. The latter is the most dangerous for food processing since contaminated fruit might be undetectable. This disease has been frequently reported in Australia, New Zealand, Argentina, Chile, South Africa and China, among other countries. Both climatic conditions and the cultivars grown in these regions are the perfect combination for the pathogen invasion. However, as Climate Change plays a key role, not only in the geographical expansion of fungal species, but in their adaptation to new environment and hosts, it would not be unexpected to find it as emerging pathogen in different apple growing regions in the near future. Other susceptible crops are apricot, peach, citrus fruit, blueberry, and bell pepper. The main risk of *Alternaria* toxins is associated with fruit-based processed food.

The lowest levels of *Alternaria* toxins recommended by EFSA are for cereal based foods for infants and young children. As with tomato and fruit-based products, cereal based foods can contain extremely high levels of these metabolites since their control is not recommended yet in the grains used as ingredients and processing do not reduce or eliminate them. High levels of *Alternaria* toxins have been reported in wheat, barley, sorghum, and other cereals worldwide. The only current regulation on an *Alternaria* toxin was established by the Bavarian health and food safety authority in sorghum/millet-based infant food due to the high levels of tenuazonic acid found in these products.

Finally, **plant-based foods, dairy and meat alternatives**, are still uncharted territory. Since the ingredients are diverse, generalisations are not valid. However, the first reports of *Alternaria* toxins in these types of products are appearing in the horizon. Plant-based, vegan and free-from food is a field that still demands significant research.

## How can we prepare for the coming changes?

We will soon be facing changes, both in food safety regulations regarding *Alternaria* toxins and in the climatic conditions on crops growing areas. The best we can do is getting to know our enemy to find the best tools to combat it. Monitoring crops for the fungi and their toxins will set us one step ahead. For farmers, the ability to recognise the infection at early stages is key to apply timely control measures. For food industry, the knowledge on how their process modifies the toxin levels present in their ingredients is an advantage to tackle the problem sooner. In a sustainable food supply chain, identifying hazards in industrial food waste is also necessary from a circular economy perspective.

*It is time to prepare for the winds of change.*

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