Possible effects of climate changes on plant diseases

Marta MARI, Camilla MARTINI

University of Bologna, Criof - Department of Agricultural Science, V. Fanin 46, 40127 Bologna, Italy,
(e-mail: marta.mari@unibo.it)

Abstract

Human activities have had a major impact on climate and ecosystems, resulting in increased temperatures, changes in the quantity and pattern of precipitation, increased CO_2 and ozone levels, drought, etc. Any change in ecosystems can affect plant diseases, because plant disease is the result of interaction between a susceptible plant, a virulent pathogen and the environment. Losses of marketable yield in crops and the reductions in growth and productivity of tree species are observed after exposure to high levels of O_3; and while pollutants can influence plant pathogens, foliar pathogens can also affect the leaf response to O_3. Moreover, some aspects associated with climate changes, such as the increase of temperature and changes in precipitation and moisture can have some effects on the fitness (number of generations, the sexual reproduction) of plant pathogens, extending the amount of time available for their reproduction and dissemination. Evidence of increased aggressiveness at higher temperatures of some pathogens has been reported, suggesting that they can adapt to and benefit from higher temperatures. For example, until 2002, when *Monilinia. fructicola* spread in several European countries, *M. laxa* and *M. fructigena* were the only pathogens responsible for brown rot in stone and pome fruits in Europe. The reason for its dissemination could be attributed to a faster capacity to growth at higher temperatures than the other two *Monilinia* species. Other important aspects concern the influence of climate change on the biology of the host and indirectly its response to pathogen attacks; for example, higher temperatures produce an extension of vegetative season and the consequent increase of secondary infections on leaves. Moreover, the persistence of a fungicide on the plant surface depends on weather conditions, in particular precipitation and temperature. Changes in duration, frequency and intensity of rain events can alter the efficacy of chemicals.

Key words: climate change, plant pathogen, fungi

Introduction

In plant pathology, the environment (considered as the combination of temperature, humidity, precipitation, UV-rays, and water, air and soil, etc.) is one of the three sides of the disease triangle and it can significantly influence the appearance and the severity of plant diseases. In the 'Anthropocene' era, the recent period of the history of Earth, human activities have had a major impact on climate and ecosystems, resulting in increased temperature, changes in the quantity and pattern of precipitation, increased CO_2 and ozone levels, drought, etc.

Up to the end of last Century, few data report the impact of climate change on plant diseases and in most cases refer only to the increase of some pollutants (mainly ozone, SO_2, CO_2) in the atmosphere and their direct effects on plants. Ozone and CO_2 concentrations have increased since the Industrial Revolution; however, they can alter plant physiology in opposite ways. Plants are subjected to acute and chronic exposure of ground-level ozone resulting in symptoms of foliar injury on sensitive plants. In addition, many physiological functions necessary for growth and reproduction are impaired by O_3 (Krupa et al., 2000). In addition, photosynthesis, leaf area, plant height, crop yield, etc. are increased in the presence of higher doses of CO_2 (Eastburn et al., 2011). Lastly, elevated CO_2 levels tend to reduce damage caused by high ozone concentrations (von Tiedemann and Firsching, 2000).

Proceedings . 50th Croatian and 10th International Symposium on Agriculture . Opatija . Croatia (37–41)

Climate changes and pathogens

Apart from the losses of marketable yield in crops and the reduction in growth and productivity of tree species caused by exposure to high levels of O_3, pollutants can influence plant pathogens, and foliar pathogens can affect the leaf responses to O_3. Generally, ozone exposure tends to decrease the incidence of disease caused by obligate parasites, increasing the disease incidence caused by facultative parasites (Table 1).

Table 1. Effect of ozone (O_3) on some fungal plant diseases[a]

Fungi	Host plant	Effect on disease[b]
Obligate biotrophs		
Puccinia graminis f. sp. *tritici*	Wheat	Decreased hyphal growth and urediospore production on O_3-injured leaves
Erysiphe graminis f. sp. *hordei*	Barley	Reduce rate of infection if exposed to sufficient O_3 during incubation
Necrotrophs *Botrytis cinerea*	Potato	Infection only in O_3 injured leaves
Lophodermium sp.	Pine	Increased severity of needle blight

[a] Manning and von Tiedemann, 1995 (modified)
[b] Observed effect was dependent on the exposure O_3 dose before or after inoculation with pathogen.

Commonly, necrotrophic and biotrophic pathogens show a different behaviour as regards their nutrition. The first obtain nutrients from dead tissues, while the second derive nutrients from living cells and maintain a prolonged and deep interaction with their host. Therefore, all climatic factors that cause or accelerate tissue death (high temperatures or O_3 levels) could favour necrotrophic pathogens. In addition, climatic factors that stimulate plant growth such as elevated levels of CO_2 or increased temperature will change the physiology of the plant, altering host colonization by biotrophic pathogens (Elad and Pertot, 2014). In particular, the decomposition of high-CO_2 litter occurs at a slow rate, increasing the biomass availability which combined with higher winter temperatures, might increase pathogen survival on crop residues accumulating the amount of initial inoculum to infect subsequent crops (Coakley et al., 1999).

Some aspects associated with climate change, such as the increase in temperature and changes in precipitation and moisture, can directly affect pathogens, enhancing their fitness in terms of number of generations and sexual reproduction (influencing the evolutionary potential of individual populations), extending the amount of time available for reproduction and dissemination. This is the case with *Phytophthora* species which increased the incidence of root rot in central Europe forest trees as a result of the rise in mean winter temperatures, the shift in precipitation from summer to winter and the tendency toward heavier rains (Elad and Pertot, 2014). In the last decades, a northward shift was observed in *Cercospora beticola* causing leaf spot in sugar beet in southern Germany, probably due to an annual mean temperature increase by approximately 0.8°C-1°C in the last century (Richerzhagen et al., 2011). In addition, strong effects of temperature on pathogen fitness traits as well as genotype x temperature interactions were found for *Puccinia striiformis* f.sp. *tritici*, the agent of wheat yellow/stripe rust. There are indications of increased aggressiveness of stripe rust isolates adapted to higher temperatures, suggesting that rust fungi can adapt and benefit from warmer climate conditions (Mboup et al., 2012). The increase of temperature contributes to the spread of pathogens in new geographic areas, where they can encounter potential hosts. Until 2002, *Monilinia laxa* and *M. fructigena* were the only pathogens responsible for brown rot in stone and pome fruits in Europe, when another species, *M. fructicola*, causing brown rot on stone fruits, was detected in France (Lichou et al., 2002). After this first report, *M. fructicola* spread in several European countries including Italy (Pellegrino et al., 2009). The reason for its dissemination could also be attributed to a faster capacity to growth at higher temperatures than the other two *Monilinia* species (Fig. 1), confirming moreover the overtaking of *M. laxa* by *M. fructicola*. In fact, from the annual monitoring data of *Monilinia* spp. Italian population, in 2010, *M. laxa* was the main species (63%) followed by *M. fructicola* (32%). After three years, on the contrary, the percentage of *M. fructicola* increased to 56 % and the incidence of *M. laxa* consequently decreased (39%).

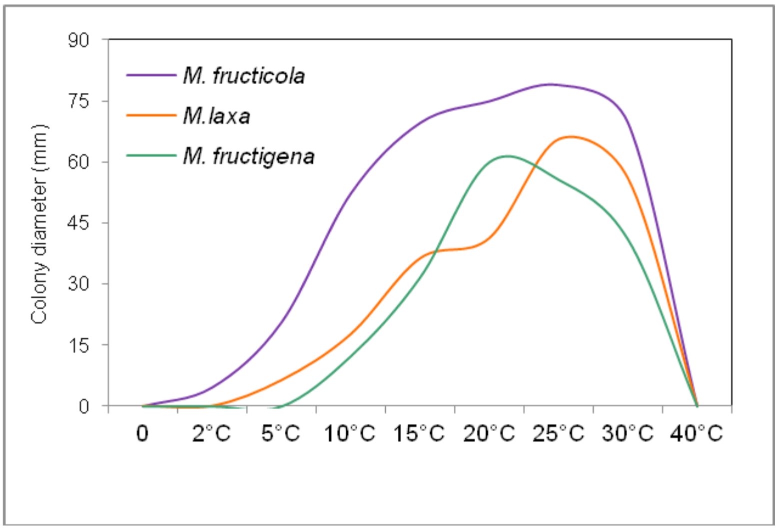

Figure 1. Influence of temperature on development of *Monilinia* spp. on malt extract agar after 7days of incubation.

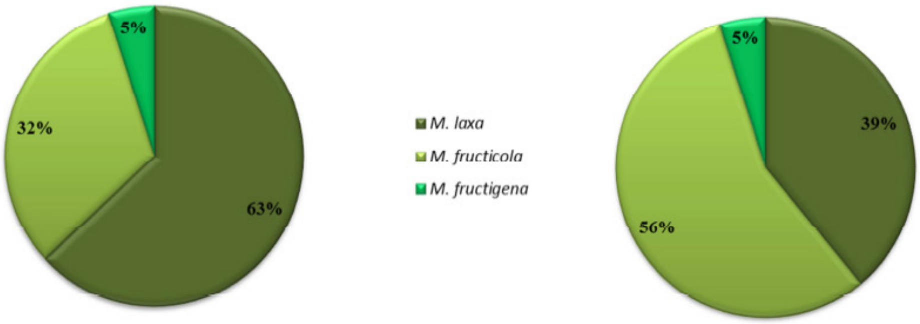

Figure 2. Monitoring of Italian population of *Monilinia* spp. in 2010 (on the left) and 2013 (on the right)

The influence of climate change on the biology of the host is often underestimated: phenology, sugar, acid, nitrogen and phenolic contents but also the number and size of leaves, stomatal density amount and composition of wax on leaves can be considerably modified by climatic conditions. Moreover, two main factors influencing a correct development of crop plants, such as prolonged dormant period during winter (chilling requirement) and heat unit accumulation, could be altered by higher temperatures in the winter resulting in an insufficient chilling period with consequent decreasing of bud breaks and prolonged flowering period. Otherwise, the increased temperatures in winter and spring can anticipate the maturation of ascospores and their release, forcing early starting of disease management. The general increase in temperature also produces an extension of the vegetative season, exposing crops to a higher number of secondary infections.

Climate changes and disease management

Plant disease management still relies on the use of fungicides although alternative methods have been under investigation for a long time. The persistence of a chemical on the plant surface depends on weather conditions, in particular precipitation and temperature. Changes in duration, frequency and intensity of rain events alter the efficacy of fungicides since they can quickly washed away. The temperature influences the degradation of pesticides, and alters the morphology and physiology of plants affecting their penetration, translocation and mode of action (Elad and Pertot, 2014). In addition, some evidence has shown the effect of temperature on the response to fungicides in *Monilinia* spp. strains which tend to be more sensitive to tebuconazole exposure at 24°C than 28°C (Fig. 3) (Martini, data *not published*).

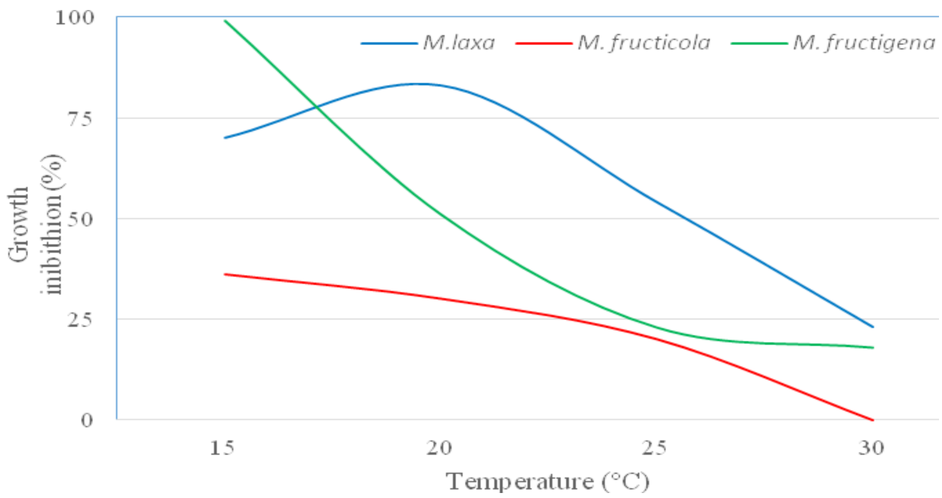

Figure 3. Influence of temperature on the inibithion of *Monilinia* spp. strains grown on tebuconazole amended medium

Pathogen life style and activity of biological control agents can be also influenced by environmental factors, although there is very little information on the impact of climate change on plant disease biological control. These are living organisms, and different climate conditions regularly affect their efficacy. For example, *Trichoderma harzianum* T39 is more active against grey mould at higher temperature and lower relative humidity level (Elad et al., 1993).

Conclusions

The impact of climate change on plant diseases requires more research. Although this topic has developed rapidly in the last few decades, there are still some gaps that need clarification. The prediction and the management of climate change effects on plant health are influenced by interactions with global change drivers. The models of plant disease development can vary under different forms of climate change, requiring different management strategies based on more participatory approaches and multidisciplinary science.

References

Coakley, S. M., Scherm, H., Chakraborty, S. (1999). Climate change and plant disease management. Ann. Rev. Phytopathol. 37: 399-426.

Eastburn, D. M., McElrone, A. J., Bilgin, D. D. (2011). Influence of atmospheric and climatic change on plant-pathogen interactions. Plant Pathol. 60: 54-59.

Elad, Y., Pertot, I. (2014). Climate change impacts on plant pathogens and plant diseases. J. Crop Improv. 28: 99-139.

Elad, Y., Zimand, G., Zaqs, Y., Zuriel, S., Chet, I. (1993). Biological and integrated control of cucumber grey mould (*Botrytis cinerea*) under commercial greenhouse conditions. Plant Pathol. 42: 324-332.

Krupa, S., McGrath, M. T., Andersen, C. P., Booker, F. L., Burkey, K. O., Chappelka, A. H., Chevone, B. I., Pell, E. J., Zilinskas, B. A. (2000). Ambient ozone and plant health. Plant Dis. 85: 4-12.

Lichou, J., Myrin, J. F., Breniaux, D. (2002). First report of Brown rot caused by *Monilinia fructicola* in peach orchards in France. Phytoma, 47: 22

Manning, W. J., von Tiedemann, A. (1995). Climate change: potential effects of increased atmospheric carbon dioxide (CO_2), ozone (O_3) and ultraviolet-B (UV-B) radiation on plant disease. Environ. Pollut. 88: 219-246.

Mboup, M., Bahri, B., Leconte, M., De Vallavieille-Pope, C., Kaltz, O., Enjalbert, J. (2012). Genetic structure and local adaptation of European wheat yellow rust populations: the role of temperature-specific adaptation. Evol. Appl. 5: 341–352.

Pellegrino, C., Gullino, M. L., Garibaldi, A., Spadaro, D. (2009). First report of brown rot of stone fruit caused by *Monilinia fructicola* in Italy. Plant Dis. 93: 668.

Richerzhagen, D., Racca, P., Zeuner, T., Kuhn, C., Falke, K., Kleinhenz, B., Hau, B. (2011). Impact of climate change on the temporal and regional occurrence of *Cercospora* leaf spot in Lower Saxony. J. Plant Dis. Prot. 118: 168-177.

von Tiedemann, A., Firsching, K.H. (2000). Interactive effects of elevated ozone and carbon dioxide on growth and yield of leaf rust-infected versus non-infected wheat. Environ. Pollut. 108: 357-363.

sa2015_p0006