INFLUENCE OF CROP MANAGEMENT ON THE IMPACT OF *ZYMOSEPTORIA TRITICI* IN WINTER WHEAT IN THE CONTEXT OF CLIMATE CHANGE: AN OVERVIEW

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Abstract. *The impact of climate change on specific biotic constrainers like pathogens and on the host-pathogen relationship is associated with changes in pathogens life cycles, increased incidence, pathogenicity, genetically recombination and aggressiveness traits, which require rethinking the integrated management strategies. However, the results of investigations are inconsistent and poorly understood in the context of climatic change. The present review is focused on the influence of crop management on Septoria Tritici Blotch (STB) disease in winter wheat in the context of climate change taking into consideration case studies in order to understand better how the components of disease cycle are affected and to identify disease risk of different agricultural practices. The response of Zymoseptoria tritici pathogen to climate change is of high interest currently in order to estimate disease risk on a large scale and to introduce new understandings in developing management strategies. Soil tillage, crop rotation, sowing date and nitrogen fertilization are considered important tools in disease control which need to be adjusted according with climatically factors for each area which affect the dispersal of ascospores and pycnidiospores of the pathogen. However, further investigation need to be done in order to highlight the impact of climate change on foliar wheat pathogens and which are the most appropriate management tools in order to control these pathogens and to enhance global food security in a changing climate.*

Key words: *Septoria Tritici* Blotch (STB), *climate change, crop management, host-pathogen interactions, Zymoseptoria tritici.*

INTRODUCTION

The intensification of world agriculture has to happen in a time, when climate is becoming less predictable, fossil fuel dependency needs to be cut, and cropland and water resources are deteriorating [ALEXANDRATOS AND BRUINSMA, 2012; POPP *et al*., 2013]. There are scenarios that climatic change will lead to a higher incidence of crop diseases (especially plant host and susceptibility, pathogen reproduction – shorter incubation - dispersal, survival and activity, host-pathogen relationship) and to a potentially larger use of pesticides [NEWTON *et al.*, 2011; SUTHERST *et al*., 2011]. The predicted impact of climate change on pathogens and host-pathogen relationship suggests that can be positive, negative or neutral depending on geographical and temporal distribution of inoculum amount and cultivars susceptibility [NEWTON *et al*., 2011; SUTHERST *et al*., 2011]. Thus, new pathogens may occur in certain regions, while other pathogens may decreases to be economically important, following geographical distribution of the host and cropping technology [COAKLEY *et al*., 1999; GHINI *et* *al*., 2008; GHINI AND HAMADA, 2008]. General tendency is that pathogens are likely to remain limited to their host distribution and not become disconnected from them. There is serious concern that climate zones will move faster that it is possible for plant populations to track them, which is expected to determine disproportionate extinction of local endemic species [LOARIE *et al*., 2009]. However, advanced knowledge about the impact of climate change on plant diseases is essential for adoption of integrated disease management measures, in order to avoid yield losses.

The ascomycete *Zymoseptoria tritici* (Desm.) Quaedvlieg & Crous (synonymous *Septoria tritici;* telemorph *Mycosphaerella graminicola*) is known as one of the most devastating foliar diseases of wheat worldwide in different climatic areas, causing *Septoria Tritici* Blotch (STB) disease [DEAN *et al*., 2012; JØRGENSEN *et al*., 2014; GURR AND FONES, 2015]. Also, *Zymoseptoria tritici* has been recorded on 26 grasses and non-graminaceous weed, but among all these only six grass species have been validated as alternative hosts of *Zymoseptoria tritici* [PRESTES AND HENDRIX, 1978; SUFFERT *et al.*, 2011].

Most studies on *Zymoseptoria tritici* are mainly focused on the host-pathogen interaction and pathogen management, but recently many authors pay a special attention to the pathogen cell biology, like cellular organization and intercellular dynamics of the pathogen itself, [MEHRABI *et al*., 2006; ORTON *et al*., 2011; SUFFERT *et al*., 2011; STEINBERG G., 2015] and fungus genetics [MEHRABI *et al*., 2006, 2009; STUKENBROCK *et al*., 2006, 2010; WITTENBERG *et al.*,2009; GODWIN *et al*., 2011; DHILLON *et al*., 2014; KELLNER *et al*. 2014; MIRZADI GOHARI *et al.*, 2014; KETTLES AND KANYUKA, 2016; SAINTENAC *et al*., 2018].

Several studies have been made on host-pathogen interaction in the context of climate change [GLADDERS *et al*., 2001; PIETRAVALLE *et al*., 2003], but despite the progress in genetic resistance and fungicide control the pathogen has proven adapt to overcoming resistance and develop fungicide resistance, therefore new approaches are needed to be integrated in disease management. Currently, there is no full genetic resistance in wheat to *Zymoseptoria tritici*, so *Septoria Tritici* Blotch (STB) disease is mainly managed by fungicides most of the cases, being estimated that 70% of the total annual fungicide used in European Union is used for this pathogen [PONOMARENKO *et al*., 2011; TORRIANI *et al*., 2015]. There was estimated that STB disease could cost the economies of France, Germany and the UK, the three main EU wheat growing countries, between €120 and 700 million [GURR AND FONES, 2015]. Despite that general adopted levels of yield losses worldwide (up to 50% of yield during severe epidemics) [EYAL *et al*., 1973, 1987] new information are necessary to be considered on specific areas under the impact of climatic changes. However, *Zymoseptoria tritici* is a pathogen that can lead to an epidemic depending on the prevalent environmental variables. The impact of climate change on the fungus *Zymoseptoria tritici* and its management is relatively understudied.

This paper aims to give an overview of the current knowledge of the impact of crop management on the fungus *Zymoseptoria tritici* in the context of climate change, which makes wheat yield more vulnerable and threaten food security. Understanding the relationship between environment conditions, crop management practices and spore dispersal could improve the control strategy of *Septoria Tritici* Blotch (STB) disease.

CLIMATICAL FACTORS INFLUENCE ON *ZYMOSEPTORIA TRITICI* IN WHEAT

The impact of climate change needs to be considered along with other factors that affect crop yields, such as specific biotic constrainers (pathogens) and its impact on the host-pathogen relationship.

Warmer temperatures are expected to occur in the north regions leading to extended areas cropped with cereals which will increase the diseases incidence and severity [GHINI *et al.*, 2008]. There were formulated three hypotheses how pathogens will be influenced by rising temperatures under climate change scenario: (i) an increased pathogen development transmission and generation number; (ii) an increased overwinter survival and reduced growth restrictions during this period and (iii) an alteration of host susceptibility [HARVELL *et al*., 2002]. GOUACHE *et al*., (2013) suggest that climatic change might reduce the average severity of STB by 2 - 6% in some areas in France, and to result in more low severity years and fewer high severity years (the probability that average severity will increase rather than decrease is between 18 - 45%, depending on location).

Among the 21 chromosomes carried by *Zymoseptoria tritici* eight of the smallest ones which are considered dispensable are supposed to be involved in faster adaptation of the pathogen to climatic changes [WITTENBERG *et al*., 2009; GOODWIN *et al*., 2011; SAINTENAC C. *et al.*, 2018], fungicide resistance [TORRIANI *et al.*, 2009; COOLS AND FRAAIJE, 2013], overcoming disease host resistance [MUNDT *et al*., 1999, MUNDT *et al*., 2002, RUDD *et al*., 2015].

Several studies have been made on the impact of environmental factors (radiation, temperature, rainfall, relative humidity, atmospheric carbon dioxide (CO_2) and other greenhouse gases) on *Zymoseptoria tritici*, suggesting that the most important role is played by temperature fluctuations, because leaves temperature is actually the temperature of the pathogen`s body that develop onto or into plant leaves, influencing significantly their life cycle [GLADDERS *et al*., 2001; PIETRAVALLE *et al*., 2003; LOVELL *et al.*, 2004; BEEST *et al*., 2009]. Warmer temperatures during early autumn will expose seedlings to an increased risk of infection with pathogen ascospores under sufficient moisture on leaves, especially on susceptible winter wheat cultivars, leading to a higher amount of inoculum overwinter. Thus, the survival of ascospores on unburied crop residues will play a large role in determining subsequent epidemic severity. Subsequent disease development results from pycnidiospores splashed vertically by rain infecting upper leaves close to each other completing several successive infections [SCHUN, 1990; LOVELL *et al*., 1997; CORDO *et al*., 1999; MCDONALD *et al*. 1999; SUFFERT *et al.*, 2011]. Pycnidiospores are carried by asexual fruiting bodies called pycnidia, developed within the substomatal cavity on wheat leaf tissues which are covered with chlorotic and necrotic lesions [KEMA *et al*.,, 1996; DUNCAN AND HOWARD, 2000].

Beside temperature the moist leaf surface plays an important role for early infections being necessary an amount of rainfall of 10 mm three consecutive wet days with at least 1 mm rain [PIETRAVALLE *et al*., 2003]. However, the pycnidiospores realise was associated with the increase in rainfall intensity seven days before the occurrence of the event and the increase in radiation 60 days before the same event. CORDO *et al*. (2017) showed that relative humidity three or five days before event was positively correlated with ascospores release and negatively correlated with radiation and temperature.

Regarding the effect of CO_2 on STB disease, VÁRY et al. (2015) showed that elevated CO_2 increased the severity of the disease and the acclimation of the pathogens leading to higher epidemics.

WHEAT CROP MNAGEMENT IMPACT ON *ZYMOSEPTORIA TRITICI* UNDER CLIMATE CHANGE

Despite contradictory results worldwide, agronomic factors are considered efficient tools to induce a break down into pathogens life cycle.

Beside altered weather patterns wheat crop practices will influence *Septoria Tritici* Blotch (STB) disease severity. Some studies emphasised that when effective management practices, including fungicide treatments, applied under no-till systems in wheat monoculture, the occurrence of *Septoria Tritici* Blotch (STB) is possible without significant yield losses [CARMONA *et al*., 1999].

In general, among crop management practices, crop rotation is considered very efficient in decreasing wheat foliar diseases and fungicide pressure, especially in no-till systems, but in case of STB short crop rotation does not decrease significantly the disease level because *Zymoseptoria tritici* pycnidiospores are more important for disease spreading and development than primary inoculum existing on plant debris [BANKINA *et al.*, 2014; FERNANDEZ *et al*., 2016; WENDA - PIESIK *et al*., 2016].

No much work has been done on the effects of minimum tillage and no tillage on STB epidemics. The impact of soil tillage on *Zymoseptoria tritici* has been studied in few different geographical areas leading to contradictory results [BAILEY *et al*., 2001; DUVIVIER *et al.*, 2013; BANKINA *et al*., 2014]. The severity of *Septoria Tritici* Blotch (STB) disease was higher in ploughed plots under conventional tillage [GILBERT AND WOODS, 2001; BÜRGER *et al*., 2012; FERNANDEZ *et al*., 2016] then in other tillage systems.

Also, delaying autumn sowing date may reduce the severity of STB disease due to the fact that wheat crop may escape from ascospores primary infections [LOVELL *et al*., 1997: GLADDERS *et al*, 2001].

Nitrogen fertilization may affect STB disease by increasing wheat tissues susceptibility and by increasing plants canopy bringing closer wheat leaves one to each other which make it easier rain splash spores dispersal and by influencing the pathogen`s life cycle itself [LOVELL *et al*., 2007; WALTERS AND BINGHAMANN, 2007; PONOMARENKO *et al*., 2011].

CONCLUSIONS

Wheat foliar pathogens are important yield-reducing components, but under climatic change conditions their attacks are likely to be more unpredictable and the amplitude larger. New studies on the impact of climate changes on foliar wheat diseases are required to make good predictions in order to design solutions to new problems challenges or to old problems becoming more severe.

Septoria Tritici Blotch (STB) disease, caused by *Zymoseptoria tritici*, is considered the most prevalent and devastating wheat disease in many countries worldwide. Studies of the impact of agronomic factors on the development of *Septoria Tritici* blotch (STB) disease have revealed high variations especially in the effect of crop rotation and soil tillage. However, some studies showed that the development of *Septoria Tritici* Blotch (STB) disease mainly depends on climatic variables and less on agronomic practices, which make this disease more difficult to be managed under climate change conditions.

A better understanding of the interractions among climatic factors, pathogens biology and crop management of susceptible/resistant cultivars are keys to managing STB disease accross different geographical areas.

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