Potential Impact of Climate Change on Geographic Distribution of Plant Pathogenic Bacteria in Central Europe

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Abstract: This review provides an overview of variety of bacterial plant pathogens which can serve as an example of how plant pathogenic bacteria can adapt very specifically to anticipated climate change in Central Europe. In the centre of attention are the themes such as: emerging of heat-loving bacteria; changes in the spectrum of pectolytic bacteria; an decrease of the frequency of occurrence of cold tolerant pseudomonads and an increase of more thermophilic xanthomonads; increased risk of xylem-limited bacteria which overwinter in insect vectors; reduced risk of damage of stone fruit trees by ice nucleation active pseudomonads and subsequent winter freeze temperatures. Of plant pathogenic prokaryotes, mollicutes and phloem-limited bacteria are not discussed in this review.

Keywords: climate variability; phytobacterial pathogens; bacterial diseases of plants; changes in geographical distribution; Central Europe

Geographical distribution of plant pathogenic prokaryotes, like other pathogens occurring in plants, is predominantly influenced by several factors such as: local climate, distribution of host plants, dispersal ability of pathogens, presence of animal vectors, adaptability of pathogens to local conditions, the ability pathogens to infect new host plants, and resistance of local cultivars. Starting from 1961, the implication of climate for plant pathogens and diseases they cause has been deeply analysed repeatedly in the Annual Review of Phytopathology series (Hepting 1963; Coakley 1988; Coakley *et al.*1999; Garrett *et al*. 2006). The review of Schaad (2008) deals with the emergence of several heat-loving plant pathogenic bacteria and the possible role of global warming in their emergence.

One of the features that characterise the world's climate is its instability. Climate change may be due to natural internal processes (within climates system) or to external processes which may be brought about by natural forcing (such a volcanic eruptions and solar variation) or anthropogenic forcing. There is consensus among climatologists that global warming is occurring and refers to the gradual increase in global average surface temperature, as one of the consequence of radiative forcing caused by anthropogenic emissions. However, confidence in attributing some observed climate change phenomena to anthropogenic or natural processes is limited by uncertainties in radiative forcing, as well as by uncertainty in processes and observations (Bater *et al.* 2008).

The purpose of this study is to review of how climate change that is anticipated in the coming decades will have impact on geographic distribution and economic importance of selected plant pathogenic bacteria in the region of Central Europe.

Of plant pathogenic prokaryotes, mollicutes and phloem-limited bacteria will not be discussed in this review.

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Climate change in agriculture sector of Central Europe

Agriculture sector is particularly sensitive to climate change. From an agricultural perspective, macroclimate can be defined as the climate above or outside a plant canopy, in contrast to microclimate, the climate within the plant canopy. While many events in plant disease cycles occur within the plant canopy, the macroenvironment often exerts a major influence on disease occurrence and pathogen dissemination (Gleaseon 2000).

The sensitivity of Europe to climate change has a distinct north-south gradient. It is anticipated that Southern Europe will be more severely affected. In Central and Eastern Europe, summer precipitation is projected to decrease, causing higher drought risk. The combined effects of higher temperatures and reduced mean summer precipitation would enhance the occurrence of heat waves and droughts. Over Europe, a considerable increase in the risk of a very wet winter was found. The predicted increase in extreme weather events (e.g. spells of et high temperature and droughts) is projected to increase yield variability and to reduce average yield (Bater *et al.* 2008).

Plant diseases in relation to climate change

It was emphasise by Coakley *et al.* (1999) that most of what has been said about plant disease in relation to climate change is based on qualitative, rule-based reasoning. For example, it seems plausible but not sure that (*i*) increased air temperature would result in a poleward expansion of the geographical range of pathogens and in more generations per year; (*ii*) elevated winter temperatures would increase survival and hence the amount of initial inoculum in many pathosystems; (*iii*) and that greater continental dryness during summer would reduce risk of infection by pathogens that require leaf wetness or saturated soils for infection.

In case of vector-borne diseases, climate influences the spatial distribution, intensity of transmission, and seasonality of diseases transmitted by vectors.

Climate change can have positive, negative or neutral impact on individual plant-bacterial pathogen interactions.

Climate is doubtless of primary importance in the distribution of plant pathogens and their host plants. The main climatic factors that pathologists are concerned with are precipitation, temperature, humidity, fog and dew, wind, and radiation. Besides, there are other factors, such as plant succession, amount of disturbance of the environment, light and length of season, the effect of which on the distribution of many plant pathogens are difficult to evaluate.

At present (i.e. 2009), about 400 bacterial plant pathogens are known (Kůdela *et al.* 2002). Bacteria multiply with astonishing rapidity, and their significance as pathogens stems primarily from the fact that they can produce tremendous numbers of cells in a short period of time (Agrios 2005). For example, generation time (doubling time) for *Pseudomonas syringae* pv. *phaseolicola* lies between 2.1–5.2 h (Klement *et al.* 1990). Growth studies in liquid medium showed the mean doubling time of four strains of *Acidovorax avenae* subsp. *avenae* decreased from 77 min to 57 min when the temperature increased from 29°C to 36°C (Schaad & Summer 1980).

Bacterial diseases of plants occur in every place that is reasonably moist or warm, and they affect all kinds of plants. Bacterial diseases are particularly common and severe in the humid tropics, but under favorable environmental conditions they may be extremely destructive anywhere (Agrios 2005). When we take into account a huge multiplicity of bacteria and their very sensitiveness and adaptiveness to environment, it is evident that study of bacterial communities can also provide climate-change clues.

The most likely effects of climate change are shifts in the geographical distribution of hosts, pathogens (including their potential vectors) and altered crop losses. Changes may occur in the type, amount, and relative importance of pathogens and affect the spectrum of diseases affecting a particular crop (Coakley *et al.* 1999). However, these authors also emphasise that the effects of climate change on plant pathogens, plant diseases and plant disease management maybe less important than changes in land-use patterns, transgenic technologies, trade activities and availability of chemical pesticides.

In the next paragraphs I will point out that the climate change can bring not only increased or any risk but also decreased risk of damage of plants by some bacterial plant pathogenes.

Emerging of heat-loving bacteria

Temperature is undoubtedly one of the most important factors influencing the occurrence and development of many plant pathogenic bacteria. Climate model simulations using future emission scenarios of greenhouse gases and aerosols suggest an increase in global mean temperature between 1 and 3.5°C by the year 2100. If there is solid evidence that global warming is occurring and if such conditions continue, heat-loving plant pathogenic bacteria should be expected to increase. A common trait of these high-temperature bacteria is an optimum growth temperature of 32–36°C (most grow well up to 41°C) whereas most other loving plant pathogenic bacteria grow best at lower temperatures.

Among heat-loving plant pathogenic bacteria that have emerged as serious problem worldwide belong following bacterial plant pathogens: *Ralstonia solanacearum*, *Acidovorax avenae* subsp. *aveane,* and *Burkholderia glumea* (Schaad 2008).

Changes in the spectrum of pectolytic bacteria

Some bacterial phytopathogens have strong pectolytic capacities that enable them to cause soft-rots (that is, tissue-macerating diseases and storage rots) in a wide variety of plants. They are economically important because of the crop loss they can cause both in the field and after harvest in transit and in storage (Pérombelon 1982; Starr 1983). Among the species of pectolytic bacteria associated with crop loss, *Erwinia* spp. (also known as *Pectobacterium* spp. or *Dickey* spp.) and *Clostridium* are economically important in temperature area. In warmer climates species of the other genera may play an important role (e.g., *Bacillus* spp., whose pathogenicity is often greater at high temperatures – Pérombelon 1982).

Ecology of soft rot erwinia reviewed Pérombelon and Kelman (1980). Soft rot erwinia differ in temperature optima and requirements. Strains of *Erwinia carotovora* subsp. *carotovora* (*Ecc*) but not *Erwinia carotovora* subsp. *atroseptica* (*Eca*) will grow at 37°C and, whereas most strains of the former are inhibited at 39°C, those of *Erwinia chrysanthemi* (*Echr*) (also known as *Dickeya chrysanthemi*) grow relatively well at > 39°C. These temperature characteristics are reflected in their host range as affected by geographical distribution. Thus, *Eca* is usually associated with the potato which, until recently, has traditionally been a cool climate crop. In contrast, *Echr* is a recognised pathogen of a wide range of tropical and subtropical crops including maize (*Zea mays* L.), pineapple (*Ananas comosus* (L.) Merr.), and rice (*Oryza sativa* L.), as well as those grown as greenhouse crops in temperate regions. The host range and geographical distribution of *Ecc* is wider and it has been associated with a range of symptoms on many plant species in both the temperate and tropical zones.

A decrease of the frequency of occurrence of cold tolerant pseudomonads and an increase of more thermophilic xanthomonads

The most of plant pathogenic bacteria belong to the *Pseudomonas* genus (ca 78 pathogens) or *Xanthomonas* genus (ca 146 pathogens). In general, pseudomonads (namely *Pseudomonas syringae* group) and the most of xanthomonads produce necrotic lesions on foliage, stems, or fruit that develop into spots, streaks, or cankers. They affect plants worldwide, causing varying amounts of damage in crops of nearly every plant family (Starr 1983).

Minimal growth temperature of *Pseudomonas* spp. is 4–5°C, whereas it is 7–9°C in *Xanhomonas* spp. (Klement *et al*. 1990) Therefore, cold tolerant pathogenic pseudomonads cause serious losses in cooler areas including Central Europe. In contrast to pseudomonads, xanthomonads are more commonly found in tropical and subtropical conditions. In spite of that, warming of Earth could change economic importance of pseudomonads and xanthomonads in crops grown in Central Europe.

Increased risk of xylem-limited bacteria which overwinter in insect vectors

Some plant pathogenic bacteria overwinter within bodies of their insect vectors. Insect transmission of plant pathogenic bacteria is usually non-specific. Examples of the specific transmission are xylem-limited bacteria *Xylella fastidiosa* subsp. *fastidiosa* causing diseases in grape (Pierce's disease), alfalfa, maple and almond and *X. f.* subsp. *multiplex* causing diseases in peach (phony peach disease), plum, almond, elm, pigeon grape, sycamore, and other shade trees. Symptoms vary from host to host but include leaf scorch, veinal chlorosis, wilt, and dwarfing (Schaad *et al*. 2004). Causal agent, *Xylella fastidiosa*, is vectored by xylem sucking insects, such as sharphooters (subfamily Cicadellinae in the leaf-hopper family Cicadellidae) and spittlebug (*Philaenus spumarius*, family Cercopidae) found also in Europe. *P. spumarius* is associated with Pierce's disease of grapevine and almoind leaf scorch, however, its relative threat as invasive vector is low in USA (Redak *et al*. 2004). During 1990s, a new insect vector, the glassy-winged sharpshooter (GWSS), *Homolodisca coagulata*, was introduced into southern California. The subsequent rapid spread and severity of Pierce's disease of grapevine attributable to GWSS was shocking. In some location, the incidence of Pierce's disease (PD) had reached alarming levels (over 50% of vines in some vineyard with PD symptoms) (Hopkins & Purcell 2002).

Climate appears to have a major role in the epidemiology of all *Xylella*-caused diseases. Most diseases caused by *X. fastidiosa* occur in North America and are particularly severe in tropical or subtropical regions with mild winters, including Mediterranean climates. They seem to be rare or absent from parts of North America with cold winters. The transition from areas of severe to rare or no Pierce's disease is gradual rather than abrupt (Hopkins & Purcell 2002). Except for report of pear leaf scorch in Taiwan in 1993 and in Kosovo in 1998 (but this findings was not confirmed later) diseases caused by *X. fastidiosa* are restricted to the American continent.

In the USA, Pierce's disease of grape caused by *X. f.* subsp. *fastidiosa* is present in the southern United States from California to Florida and in Central America. There is a real risk of introducing *Xylella fastidiosa* into the EPPO region where this quarantine pest has not yet been found and constitutes a serious threat principally to the Mediterranean grapevine industry (Bazzi *et al*. 2008), but also for other host plants such as deciduous forest and amenity trees. So, measures are already taken to present the entry of *X. fastidiosa* in European countries but it is also very important to prevent the entry of efficient vectors such as *H. coagulata*.

Reduced risk of damage of stone fruit trees by ice nucleation active pseudomonads and subsequent winter freeze temperatures

Bacterial canker and dieback, caused by *Pseudomonas syringae* pv. *syringae* and *P. s.* pv. *morsprunorum*, are well known on stone fruit trees in all major producing area of the world (Hattingh & Roos 1995). They serve as nuclei for ice formation and therefore cause frost injury to plants at temperatures just below 0°C (Lee *et al*. 1995).

The most characteristic symptoms caused by both *Pseudomonas syringae* pathovars are formation of cankers, a sunken necrotic lesion outside the xylem cylinder or bark necrosis, accompanied by gum exudation. Cankers develop on trunks, lateral branches, twigs at the base of flower and leaf buds, in pruning wounds and at the base of infected spurs. Gum often exudes from cankers, especially early in the growing season. The dieback symptom, progressive death of shots and branches starting at the tip, sometimes has been called apoplexy of stone fruit trees. The disease can have a significant effect on fruit production on mature trees. The severity of damage varies from subtle, almost undetectable effects to rapid death of trees in nurseries and orchards. A combination of several predisposing elements, particularly climatic and soil factors, favours disease expression (Klement *et al.* 1974; Hattingh & Roos 1995).

The trunk and branches of trees usually are infected in autumn and late winter. The bark necrosis only develops during the winter but dieback and canker symptoms appear in spring or summer. Klement *et al.* (1974) demonstrated that both *P. syringae* and freezing temperatures were required for the development of bacterial canker. Severe damage from bacterial canker in apricot tree inoculated with *P. syringae* occurred only with in association with orchard temperature well below freesing. Vigouroux (1974) reported a similar interaction between freezing and *P. mors-prunorum* f.sp. *persicae* (= *P. syringae* pv. *persicae*) in the development of bacterial canker in excised peach twigs. Veaver (1978) provide direct evidence that development of bacterial canker in peach twigs is associated with below-freezing temperatures that follows mild periods during winter. A freezing-thawing cycle created a water-soaked condition in the bark of shoots of peach and apricot that induced a quick ingress (1 min) and a noticeable spread (15–35 mm) of bacterial and dyes in tissues. This phenomenon may explain the decisive effect of low temperature on several diebacks and cankers of fruit trees caused by pseudomonads (Vigouroux 1989).

If the frost-line moves north in the Northern Hemisphere, higher winter temperatures could be accompanied by lower cold and freeze damages in Central Europe. Simultaneously, reduced risk of damage of stone fruit trees by bacterial canker and dieback could be expected. Although plant diseases are a crucial constrain on plant productivity, these is only limited knowledge about how climate changes will affect plant health.

Climate change and plant health care system

The predicted changes in future climate may affect growth of crop plants and their interaction with plant pathogens. It seems therefore possible to meet any predicted harmful effects. However, in spite of the fact that plant diseases are crucial constrain on plant productivity, the effects of changing weather systems on plant health are difficult to show conclusively. Climate change is likely to be a gradual process that will give researchers, plant breeders, plant health care practitioners, managers and farmers some opportunity to adapt.

Both predicted (and unpredicted) disease consequence of climate change on plant health can most likely be minimised by such manners as follows: (*i*) to build a solid knowledge base on the impact a consequence of climate change for various parts of the world (Anonymous 2009); (*ii*) to determine the potential for adaptation under potential changes in pathogen pressure due to climate change (or other factors) (Garrett *et al.* 2006); (*iii*) to maintain a high index of suspicion for changes in the plant pathosystem; (*iv*) to monitor systematically occurrence of diseases and animal pests in each field and region and keep records of severity, frequency over time; (*v*) to develop new varieties adapted to changed climate through traditional or transgenic methods; (*vi*) the farm advisory system could be used not only to disseminate knowledge but also to adopt and introduce the new integrated control of organisms injurious to plants.

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