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Réchauffement climatique, quels impacts probables sur les vignobles ?
Global warming, which potential impacts on the vineyards?
28-30 mars 2007 / *March 28-30, 2007*

1

Potential effects of climate change on distribution and activity of insect vectors of grapevine pathogens

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Abstract

The impact of changing climatic conditions on viticulture is currently mainly discussed with respect to alterations in grape physiology, adaptation of cultivars and cultural practice. However, pests and diseases of grapevine are influenced by changing climate, too. They are affected either directly through impacts on their life history and epidemiology or indirectly by changes of grapevine physiology and phenology.

This presentation will focus on potential risks of changing climate caused by arthropod vectors of grapevine pathogens particularly in cool climate viticulture of the northern viticultural areas of Europe. More or less complex pathosystems consisting of grapevine, pathogens, vector(s) and sometimes alternative host plants need to be considered, particularly since the respective pathogens are graft transmissible and may be spread independent from their vectors by propagation material.

Known arthropod vectors in European viticulture belong to the order Hemiptera. They transmit either grapevine viruses (Coccoidea; soft scales and mealybugs) or phytoplasmas (Auchenorrhyncha; leafhoppers and planthoppers). Many are Mediterranean species that depend on high ambient temperatures and are not yet present or restricted to greenhouses or to sites with favourable microclimatic conditions in the northern viticultural regions. Rising temperature could increase the risks of introduction of vectoring species such as virus transmitting mealybugs or may lead to an extension of their natural range to the North. This is currently happening with the leafhopper *Scaphoideus titanus*, the vector of Flavescence dorée. Other species with possibly benefit grow an increase in their population density and an extension of the plant host range or suitable habitats, which might result in a higher vectoring activity. Transmission of Ampelo-and Vitiviruses by soft scales and of Bois noir phytoplasma by the planthopper *Hyalesthes obsoletus* are examples for this scenario.

The examples presented here are based on field observations. Detailed studies would be necessary to reliably describe the effects of climate change and to assess the risks. An interdisciplinary approach, bringing together the expertise of biologists, plant pathologists and meteorologists, could help to investigate these interactions more extensively. A more detailed knowledge of the major environmental factors that influence the particular pathosystems could help to develop tools to scale down risk assessment to individual viticultural areas.

Key words: grapevine, virus, phytoplasma, vector, climate change

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The impact of climate change on viticulture is mainly discussed with respect to grapevine phenology, adaptation of cultural practice or necessary changes in cultivars (Duchêne & Schneider, 2005; Jones *et al.*, 2005; Schultz, 2000; Seguin & Garcia de Cortazar, 2005, White *et al.*, 2006). Systematic investigations on the consequences of changing temperature, precipitation or

Réchauffement climatique, quels impacts probables sur les vignobles ?
Global warming, which potential impacts on the vineyards?
28-30 mars 2007 / *March 28-30, 2007*

2

CO_2-concentration on grapevine pests and diseases are still few (e.g. Chakraborty *et al.*, 1998; Coakley *et al.*, 1999; Garret *et al.*, 2006; Salinari *et al.*, 2006) although various observations indicate that significant alterations are going on already.

Effects of climate change on insects in general have been studied intensively. Most studies focused on butterflies and other taxa that can be considered as 'indifferent' for agricultural ecosystems (Bale *et al.*, 2002; Parmesan, 2006) while only a few reports have been published for agricultural pests (Cammel *et al.*, 1992; Cannon, 1998; Neilson & Boag, 1996; Porter *et al.*, 1991). Temperature is a main abiotic factor for poikilothermic insects (Parmesan, 2006). It directly effects development and phenology of insects, their reproduction and mortality, their ability to exploit particular host plants, and their geographic distribution range (Bale *et al.*, 2002). The food ressource of phytophagous insects is influenced both quantitatively and qualitatively by climate effects on the availability, phenology and quality of suitable host plants (Hodkinson, 1997).

Many insect vectors of plant pathogens are xerothermic Homoptera. Three examples for potential or already occurring changes of the vector situation in European cool climate viticulture will be presented in this paper.

I. Scale insects and grapevine viruses

Viruses are major grapevine pathogens that have been distributed worldwide together with grapevine. Ampeloviruses associated with grapevine leafroll disease (GLR) and Vitiviruses that are considered to be the causal agents of grapevine diseases of the rugose wood complex are of high economic importance (Martelli & Boudon-Padieu, 2006). Symptom expression and economic damage are influenced by climate and considered to be more significant in Mediterranean climate than in cooler regions.

Both groups of viruses are transmitted and spread by scale insects (Homoptera: Coccoidea) (Martelli & Boudon-Padieu, 2006). Soft scale (Coccidae) and mealybug (Pseudococcidae) species have been identified as vectors in Mediterranean areas and overseas. The significance of vector transmission in relation to the spread of GLR by planting material is yet unclear for northern viticultural areas, although different endemic species of Coccidae and Pseudococcidae from Northern France have been shown to be able to transmit GLR associated viruses (Sforza *et al.*, 2003).

Risks related to climate change may evolve from an increasing abundance and vectoring activity of endemic species and from the establishment of field populations of Mediterranean mealybug species of the genera *Planococcus* and *Pseudococcus* that are currently restricted to greenhouses in central Europe (Hoffmann, 2002). Field studies of the distribution of potential GLR vectors and of the spread of GLR in newly planted vineyards are currently carried out by INRA, Dijon, in different northern viticultural areas of France. First results not only indicate a considerable increase of the number of infected vines within a few years after planting, but also show the presence of different soft scale and mealybug species in the affected vineyards. The occurrence of some of these species appears to be correlated with the spatial distribution of virus-infected vines, thus pointing towards a role of mealybugs in the field spread of leafroll in temperate regions, too.

Réchauffement climatique, quels impacts probables sur les vignobles ?
Global warming, which potential impacts on the vineyards?
28-30 mars 2007 / *March 28-30, 2007*

3

Temperature is the key climate parameter that influences the occurrence and the density of insect vectors (Bale *et al.*, 2002). Mean autumn and minimum winter temperatures have been identified as key factors for the establishment of field populations of Mediterranean mealybug species (Peacock *et al.*, 2006) while rising summer temperatures are likely to favor the development and population density of endemic potential vectors. The alternative overwintering strategy of some mealybug species, e.g. *Heliococcus bohemicus*, that hibernate either as adult females or as second instar larvae might be a measure to adapt to different abiotic conditions and could favor survival of field populations. Species that are able to hibernate in their active stages show increased winter survival in warm winters (Bale *et al.*, 2002). Considerable increases in minimum winter temperatures have been reported for northern and central Europe (Heino *et al.*, 1999).

II. Grapevine Yellows and Auchenorrhyncha

Grapevine yellows (GY) are diseases of grapevine associated to phytoplasmas. They are known from many viticultural areas world wide (Boudon-Padieu, 2003). While the symptoms caused by different GY are similar, they show considerable differences in epidemiology due to the different life history of their respective vectors (Boudon-Padieu, 2005). All vectors of GY identified so far are Auchenorrhyncha (leafhoppers and planthoppers) and transmit the phytoplasmas in a propagative and persistent manner. The most important GY in Europe are Flavescence dorée and Bois noir (Boudon-Padieu, 2003).

III. Flavescence dorée and *Scaphoideus titanus*

Flavescence dorée (FD) is the most destructive GY and a quarantine disease for Europe. It is caused by phytoplasmas of the elm-yellows (16Sr-V) group and transmitted by the leafhopper *Scaphoideus titanus* Ball (Schvester *et al.*, 1961)*,* a nearctic species that has been introduced to Europe presumably at the beginning of the 20th century. *S. titanus* is a strictly ampelophagous leafhopper that deposits its eggs in the bark of two and one year old grapevine wood. Larvae and adults feed exclusively on grapevine (Vidano, 1964, 1966). They acquire the phytoplasmas from infected vines and transmit them to other vines. Due to the high efficiency of this epidemic cycle FD may spread epidemically where infected vines and high populations of *S. titanus* occur together (Bressan *et al.*, 2006).

Originating from the northeastern part of North America where it lives on wild species of *Vitis* (Vidano, 1966; Maixner et al, 1993), *S. titanus* tolerates cold winters but requires warm summers. After its introduction, the leafhopper spread from southwestern France over Italy to the Balkans and to Spain and Portugal (Bertin *et al.*, 2007). It is currently distributed around the 45th degree of latitude in areas where winter temperature is sufficiently low to break the diapause of hibernating eggs and summer temperature allows the completion of the life cycle of this monovoltinous species. As mean temperatures during growing season are rising, *S. titanus* is currently extending its range to the north (Boudon-Padieu, 2000). Viable populations are now present in Burgundy in France, the Lake Geneva area of Switzerland, and occurred recently in southern Austria and Hungary, adjacent to areas that had been colonized before. Whether this phenomenon is only due to the increased probability of successful establishments of new populations of this species on the northern border of its range or if additional phenomena such as temperature driven enhanced migration activity (Parmesan, 2006) plays a role, is not known. The occurrence of isolated but viable populations of *S. titanus* outside its continuous distribution

Réchauffement climatique, quels impacts probables sur les vignobles ?
Global warming, which potential impacts on the vineyards?
28-30 mars 2007 / *March 28-30, 2007*

4

range as well as studies of the genetic structure of European populations of this leafhopper point to a spreading by grapevine wood such as propagation material (Bertin *et al.*, 2007). Rising temperatures are likely to extend the area where this vector could be introduced successfully. A comparison of temperature profiles at the current northern border of the range of *S. titanus* with German regions that are still free of this vector reveals a high risk of successful introduction at least in the southernmost viticultural areas such as Baden (Maixner, 2005). Since there is a high risk of outbreaks of FD wherever *S. titanus* is present, insecticide treatments against *S. titanus* would be necessary as a consequence of its introduction. This would severely interfere with the current pest control strategies in Germany that aim at minimizing insecticide and acaricide use in viticulture.

IV. Bois noir and *Hyalesthes obsoletus*

Bois noir (BN) is caused by phytoplasmas of the stolbur (16SrXII-A) group (Daire *et al.*, 1993) that are endemic to Europe where they occur in various wild and cultivated plants beside grapevine (Langer *et al.*, 2003). The natural vector of BN is *Hyalesthes obsoletus* Signoret, a planthopper of the family Cixiidae (Maixner et al., 1995; Sforza *et al.*, 1998; Alma *et al.*, 2005). *H. obsoletus* is a Mediterranean species that reaches the border of its distribution range in the northern viticultural areas, where this xerothermic insect is restricted to habitats with most favorable microclimate conditions such as vineyards on the steep slopes of river valleys (Maixner & Langer, 2006).

BN, in contrast to FD, is not spread from vine to vine, but is transmitted solely from wild herbaceous plants to grapevine (Maixner *et al.*, 1995). Such weeds represent a natural reservoir of the pathogen in the vineyard environment. Due to the existence of host specific strains of the pathogen and host adapted populations of the vector, at least two different epidemic cycles are relevant for the transmission of BN to grapevine (Langer and Maixner, 2004). One cycle includes stinging nettle (*Urtica dioica*) and a second comprises bindweed (*Convolvulus arvensis*) as the host plant of the vector and natural source plant of type I and II of the BN-associated phytoplasma, respectively. Until recently, *H. obsoletus* was almost exclusively restricted to bindweed in the northern part of its range (Langer & Maixner, 2004) while nettle is the preferred host plant in areas like northern Italy (Alma et al., 1987). The restriction to one or a few of those host species that are used in the center of an insect species range has been observed at the range limit of other insects like butterflies (Thomas *et al.*, 2001) or psyllids (Hodkinson, 1997), too. Recently, and apparently triggered by the extraordinary hot summer of 2003, *H. obsoletus* started to exploit *U. dioica* as a host plant in most of the German wine-growing areas as well. The 2003 climatic anomaly had similar effects on other species, for example the pine processionary moth *Thaumetopoea pityocampa* in France that was able to rapidly expand its altitudinal range (Battisti *et al.*, 2006). The rapid increase in population density of the planthopper in the newly colonized nettle habitats is followed by a rising infestation of the vector populations by the nettle-restricted type I of BN-phytoplasma and the subsequent increase of BN incidence in the affected vineyards. All recent new outbreaks of BN in Germany, either in 'traditionally' affected or in newly infested areas, are due to this type of BN-phytoplasma that had been extremely rare not more than five years ago. In addition to the exploitation of *U. dioica* in its typical habitats, *H. obsoletus* started to spread on this plant to sites with less favorable microclimatic conditions such as vineyards in rather flat areas.

Réchauffement climatique, quels impacts probables sur les vignobles ?
Global warming, which potential impacts on the vineyards?
28-30 mars 2007 / *March 28-30, 2007*

5

All stages of the monovoltinous *H. obsoletus* except of adults live inside the soil where they feed on the roots of their host plants. The adult planthoppers emerge in summer and feed on leaves of herbaceous plants for about six to eight weeks. Although the insect develops in the soil, the start of the flight activity can be calculated with sufficient accuracy using day-degree sums of the air-temperature (Maixner & Langer, 2006). Our analyses of weather-data and the flight activity of *H. obsoletus* revealed a significant negative correlation between the mean temperature from April to June and the date of the first emergence of adult vectors for both, the bindweed and nettle populations. However, the start of the flight activity of nettle populations is delayed by two to three weeks compared to bindweed populations at the same locations. The day degrees required for the start of flight activity of nettle populations are about 12 % higher than on bindweed, which suggests nettle to be a less suitable host plant compared to bindweed. This could be explained by a lower growth rate of *H. obsoletus* immature stages on nettle, since food quality has an influence on the growth rates of immature insects (Scriber & Slansky, 1981; Scriber & Lederhouse, 1992). The significant increase in the yearly mean temperature in Germany over the last 30 years (Lüers, 2003) could be the reason for *H. obsoletus* to be able to use a previously non suitable host plant like nettle due to an increasing growth rate of immature stages. However, the growth rate of another Auchenorryhncha species, the spittlebug *Philaenus spumarius*, was not affected by temperature (Masters *et al.*, 1998). Furthermore, a temperature induced higher growth rate would not explain that *H. obsoletus* is able to live on nettle in less favorable microhabitats, too. We hypothesize therefore that the phenomenon of the recent exploitation of nettle as an additional host plant might be due to the climate change induced prolonged growth period of *U. dioica*, leading to an extended feeding interval of *H. obsoletus* nymphs in autumn and spring and thus compensating for the lower growth rate of this planthopper on nettle. If this influence of an extended growing season was more significant than the temperature dependence of the growth rate, this could explain the observed colonization of nettle by *H. obsoletus* also at microclimatically less favorable sites. The lengthening of both, the climatological and the phenological growing season in Germany is well documented and mainly due to increased daily minimum temperatures, leading to a longer frost free period (Menzel *et al.*, 2003).

V. Conclusions

The impact of climate change on viticulture is already visible. Current observations indicate that changes take place in disease and pest occurrence and economic damage due to climate change, but there are many uncertainties. A clear understanding of how disease vectors are influenced, either through direct or indirect effects, is lacking, not at least because complex disease systems consisting of grapevine, pathogens, vectors and alternative host plants are involved. While meteorological records are on hand for long periods, data of systematic surveys for disease spread and severity as well as occurrence, density, and changes in distribution range of vectors are lacking for the most part. Particularly in the case of xerothermic species moving northwards, microscale climate data are required to analyze and explain the current habitat selection and distribution, and to assess future risks for individual growing areas or particular viticultural sites. The consequences of climate change for grapevine diseases, pests or their natural antagonists, and for control strategies go beyond the question of insect vectored pathogens and are closely related to adaptation strategies in viticulture and alterations in grapevine phenology. Cool climate viticulture most probably will face more damage by berry rots, higher population densities or more generations of pest insects and mites and an increasing significance of yet secondary pests in the future, but the effects are likely to differ among pest species depending on the specific modes of interaction.

Réchauffement climatique, quels impacts probables sur les vignobles ?
Global warming, which potential impacts on the vineyards?
28-30 mars 2007 / *March 28-30, 2007*

6

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Réchauffement climatique, quels impacts probables sur les vignobles ?
Global warming, which potential impacts on the vineyards?
28-30 mars 2007 / *March 28-30, 2007*

7

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Réchauffement climatique, quels impacts probables sur les vignobles ?
Global warming, which potential impacts on the vineyards?
28-30 mars 2007 / *March 28-30, 2007*

8

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