Influence of Climate Changes in the Czech Republic on the Distribution of Plant Viruses and Phytoplasmas Originally from the Mediterranean Subtropical Region

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Abstract: Results of research aiming at monitoring of climate changes impact on plant pathogens distribution such as *Zucchini yellow mosaic virus* (ZYMV), quarantine *Plum pox virus* (PPV) and quarantine phytoplasma European stone fruit yellows (ESFY) are presented here. ZYMV has spread from Northern Italy across Austria up to Central Moravia and Bohemia. PPV has been continuously spreading from the lowlands of Central Bohemia and Moravia up to plains. Later, from the sixties and seventies of the last century, due to climate warming and human activities the virus quickly spread to uplands, foothills and mountains of the Czech Republic. Phytoplasma ESFY was spreading in a manner similar to ZYMV in the eighties of the twentieth century from Northern Italy and currently is affecting mainly apricot and peach trees in Southern Moravia.

Keywords: plant viruses; phytoplasma; ZYMV; PPV; ESFY; spreading; climate changes; Czech Republic

The climate changes and global warming due to human activities have had substantial and by no means insignificant impact on the quality of life on the Earth and living conditions of humans, animals and plants. The possibility of growing e.g. apricot or peach in Europe has been moving into more northern areas, so nowadays it is possible to grow apricot trees, peach trees and grapevine in certain regions in Poland up to Warsaw. The same is of course true also for the Czech Republic, where these cultures can be these days grown in 150–200 m higher altitudes than thirty or forty years ago. The average of year temperature grown up 2.1°C in Prague-Ruzyně, Crop Research Institute in the period 1979–2008 (Prášilová 2009 personal communication; Prášil & Prášilová 2001). E.g. the average of year temperature was 7.4°C in 1979, and 10.0°C in 2008 according to measurement of meteorological station in Prague-Ruzyně.

In accord with mentioned facts and threats, important pathogens (including quarantine) are spreading to the north and to the higher altitudes. In this report, examples of plant viruses and phytoplasmas spreads are presented. In a number of cases, however, it is a combination of climate changes and direct human spread that causes it. The spread of *Zuccini yellow mosaic virus* (ZYMV), virus of significant economic importance, from Northern Italy across Austria to the Czech Republic is presented. In the Czech Republic, the way of spreading from the South Moravia regions bordering with Austria up to other regions of Central Moravia and Central Bohemia was recorded. The spread of quarantine virus, *Plum pox virus* (PPV) from Bulgaria is described as well as detailed history of PPV spread in plums from the second half of the twentieth century until now in the Czech Republic. Furthermore, progressive spread of PPV from central lowlands to the medium and

Supported by the Ministry of Agriculture of the Czech Republic, Project No. MZE 0002700604.

high altitudes of Bohemia and Moravia from the second half of twentieth in the last century and current distribution of the virus in foothills and mountain areas of the Czech Republic and severe distribution of PPV in lowlands are described. Briefly, distribution of quarantine phytoplasma European stone fruit yellows (ESFY) in Southern Europe and its spread and distribution in the Czech Republic is evaluated.

RESULTS AND DISCUSSION

Typical example of a dangerous virus spread without contribution of humans is fast spread of *Zucchini yellow mosaic virus* (ZYMV) causing enormous losses in cucurbitaceous vegetables production. *Potyvirus* ZYMV or, better to say, the disease caused by the virus was first recognised in 1973 in Northern Italy in courgette plants. Lisa *et al*. (1981) identified the infectious agent and gave it a name of ZYMV. At the same time, the disease was observed in Southern France and the virus was called *Muskmelon yellow stunt virus* (Lecoq *et al*. 1981). In the following years, ZYMV due to fast aphid-based spread crossed the Alps or bypassed them through Slovenia to Austria. In 1990, 17 years from the first recognition in Italy, the virus was found in former Czechoslovakia, in South Moravia close to border with Austria (Chod & Jokeš 1991). Further spread of ZYMV in the Czech Republic is recorded in a great detail. The way of spreading from the South Moravia regions bordering with Austria up to other regions of Central Moravia and Central Bohemia was recorded.

The distribution of the virus was studied by Ing. Jiří Svoboda, who took hold of the idea in a complex way, including protection means in his Ph.D. thesis. Also, the State Phytosanitary Administration bodies took an active part in the research and even appointed a commission specialising in this area. The ZYMV problem solving is possible to be presented as factual and practical cooperation of Virology Department of Crop Research Institute in Prague and the State Phytosanitary Administration.

After the first sporadic occurrence of ZYMV in the Czech Republic the virus spread progressively. In 1997, there were less than 30 ha of gherkins and pumpkins infected in Southern Moravia. In years 1998–2000, significant occurrence of ZYMV was observed already in two Southern Moravian regions, Břeclav and Znojmo, both regions bordering with Austria. In 2001, ZYMV was found in two more regions, Brno and Hodonín, regions neighbouring the previous two. ZYMV infected in the above stated regions mainly gherkins, but also courgettes, pumpkins and cucumbers, with infections spreading on 100 hectares of crops, ranging from 20% to 80% (Svoboda & Polák 2002). In 2003, the first occurrence of the virus was recorded in Central Bohemia (Svoboda 2004) and in 2006 ZYMV was sporadically distributed in Central Bohemia and common in Central Moravia in regions Prostějov and Blansko (Svoboda 2006). ZYMV does not belong to quarantine viruses; nevertheless, it causes big economic losses in cucurbitaceous vegetables, where it produces strong malformation of fruits (Figure 1) and if the plant is infected at an early stage, fruits are not produced at all. The protec-

Figure 1. Malformation of fruit of zucchini cv. Zelená naturally infected with ZYMV (photo J. Svoboda)

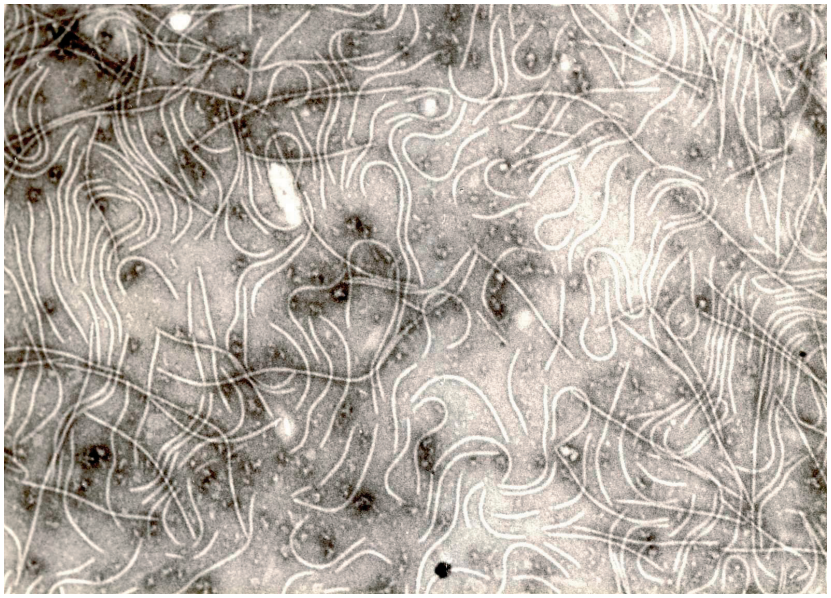

Figure 2. Filamentous particles of PPV, 750 nm long, electronogram of purified virus (photo M. Jokeš)

tion against the virus is quite difficult; apart from agrotechnical measures it is necessary to grow resistant varieties. Japanese cultivars with high level of resistance were developed recently (Svoboda 2009). The research and engineering of cultivars with transgenic resistance to ZYMV is carried out at the USDA Agricultural Research Station in Charleston, South Carolina, USA.

Climate warming in the last decades has also had impact of another Potyvirus spread (Figure 2), one of the most harmful quarantine virus, *Plum pox virus* (PPV). In this case, however, it is a combination of climate warming and spread of infected propagation material, mainly infected grafts and buds, which has been causing the spread.

Until now in all scientific publications from the Czech Republic on plum pox and PPV was declared that the first occurrence of the virus in the CR was proved in 1952 (Smolák & Novák 1956). However, plum pox occurred in Bohemia and Moravia long time before that. Smolák already in 1926 (Smolák 1926) described a mosaic disease in mirabelle in the Czech Republic that has been most likely caused by PPV. Blattný (1930) found symptoms on *Prunus insititia* in Central Bohemia matching *Plum pox virus* symptoms and Blattný (1931) and Baudyš (1932) described degeneracy of plum also matching symptoms of PPV. These findings of Czech phytopathologists were published in 1933 by an excellent virologist and phytopathologist Prof. Dr. Dmitrij Atanasoff in the first monograph about plum pox Šarka po sliviť. Edna nova virusna bolesť, in the annual report of Sophia University, Faculty of Agronomy and Forestry (Atanasoff 1933). In this monograph, there are excellent photos of PPV symptoms on leaves and fruit of plum variety Kjustendilská, but also on other plum and greengage cultivars. Furthermore, Prof. Atanasoff in this monograph reports that he saw typical PPV symptoms on fruits of plum cultivar Brňanka on a market, when visiting Brno in August 1932. Therefore, occurrence of plum pox in the twenties and thirties of the last century is in the Czech Republic confirmed in scientific literature only in Central Bohemia and Central Moravia. In the forties of the 20th century, plum pox was confirmed in region Chrudim and speculations about disease importation from Bulgaria arose. Then, in the fifties, observations and records of Plant Protection Inspectors about wide spread of plum pox in region Plzeň are known. Also, our first personal observations were recorded in these years. At that time, plum pox was not present in regions Podzvičinsko and Novopacko (Miletín and Lázně Bělohrad). This situation remained in sixties and seventies and is recorded in thesis Occurrence of Viral Diseases in Fruit Nurseries and Orchards in Region Jičín (Polák 1964). At that time, plum pox did not cross the border of Chlum under mountains Krkonoše and the most northern area where it could be found was in lowlands of regions Hořice, Turnov and Jičín (Figure 3).

Very similar situation was in the South-western Bohemia. Domažlice highlands were plum pox free at the time. That was in fifties, sixties and seventies. Already in 1963, plum pox was recorded in apricot, plum and peach nursery in Hořice in foothills of Krkonoše (Figure 4), where the disease

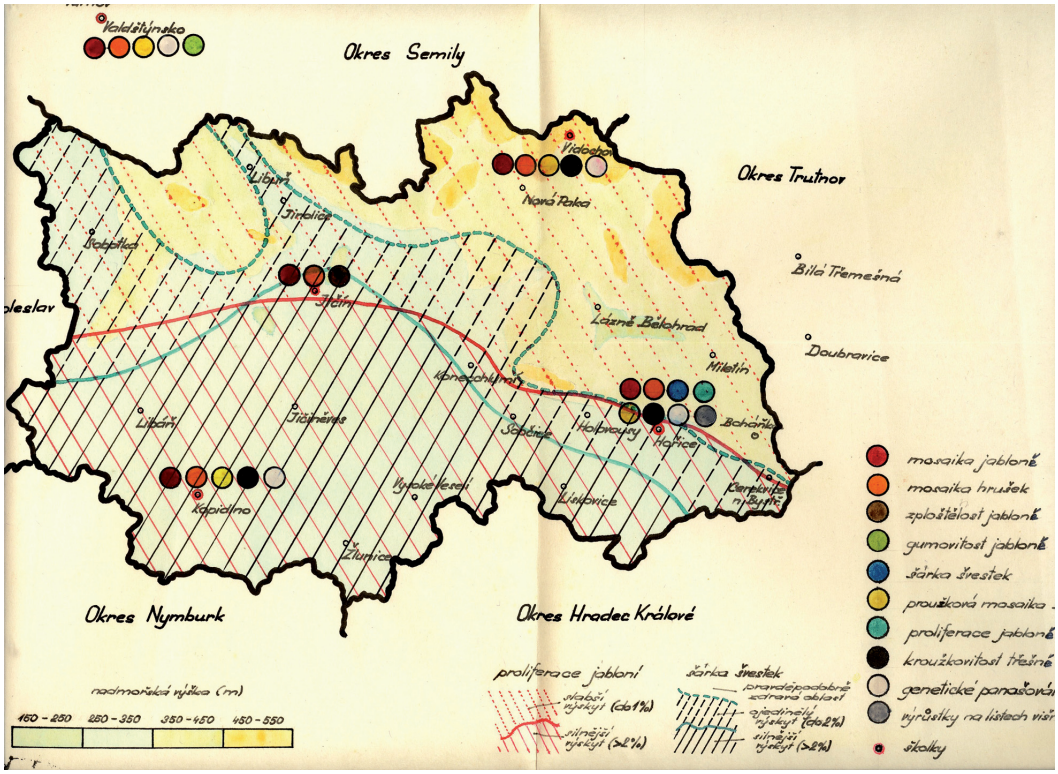

Figure 3. Distribution of virus diseases in fruit nurseries, orchards and environment of district Jičín in 1963 (orig. J. Polák)

was named "Yellow streak peach disease". The disease was found in one to tens of individual trees for each variety. In the plums, plum pox was recorded in cultivars Švestka domácí velkoplodá, Esslingenská, Wangenheimova, Althanova, Oullinská, Ananasová, Zelená ryngle from 0.1% to 16.66%. The varieties were usually grafted on rootstock *P. myrobalana*, some of them also on Wangenheimova. The highest occurrence of PPV was recorded for *Prunus triloba* (33.75%), where the rootstock was *P. domestica* originally from Hrubčice. Plum pox was also recorded on apricot cultivars Rakovského and Bredská (rootstock Damas C) and on peach cv. South Heaven. In the same year in Hungaria, Dr. Mária Németh first described plum pox in peach (Németh 1964). PPV was therefore first described in peach independently in two different countries, the Czech Republic and Hungaria.

In the eighties and nineties, outbreak in PPV spread occurred in higher altitudes and in remote areas of Bohemia and Moravia (Polák 1997, 2002). It is possible to say that after fifty years long stagnation in virus spread, respectively in its slow spread in lowlands, PPV quickly spread into foothills in altitudes from 400 to 700 m a.s.l. This fast spread was influenced not only by climate warming, but also by import of infected propagation material into altitudes in which fruit nurseries did not exist

Figure 4. Symptoms of PPV in leaves of peach cv. South Haven, nursery Hořice, 1963 (photo J. Polák)

before, in spite of all measures taken in the nurseries to prevent it. Even though the occurrence of plum pox in nurseries bordering with foothills regions was rather scarce, one or few sources of infection imported into the region were enough for further fast spread of the virus due to aphid transmission. Nowadays, *Plum pox virus* is distributed widely not only in lowlands, plains and valleys, but also in the foothills and spreading up to the mountain areas with altitudes as high as 800 m a.s.l. For example, plum trees infected with PPV were localised on the way up to Radhošť in North-Eastern Moravia or in Novohradské mountains, South Bohemia. Lower rate of infection is recorded only in southern Bohemia and Moravia. PPV is spread in the Czech Republic in different cultivars of plum, in myrobalan, in blackthorn bushes (only lowlands and valleys), in cultivars of apricot and peach. In natural conditions PPV has not yet been confirmed in cherry and sour cherry trees. The milder strain of PPV, PPV-D is prevalent in the Czech Republic – around 95% of all infected trees are infected with this strain. Occurrence of highly pathogenic strain PPV-M was recorded only sporadically in the Czech Republic (Polák 2004; Polák & Pívalová 2005). In Southern Moravia, there are scarce infections of strains PPV-M and PPV-Rec, around 2.5% of plum and myrobalan trees are infected with each strain (Polák & Komínek 2009). It does not mean though that in the Southern Moravia there are not orchards of apricots and peaches grown from imported propagation material almost thoroughly infected with strain PPV-M. Fortunately, these are overmatured stands and as such are gradually disposed of. The occurrence of strains PPV-C, PPV-EA and PPV-W has not yet been recorded in the Czech Republic so far. The most efficient mean of protection against this virus is growing of resistant or even immune varieties of stone fruit trees (Figure 5).

The last example is of quarantine phytoplasma spread, European stone fruit yellows (ESFY), syn. *Candidatus Phytoplasma prunorum* (Seemüller & Schneider 2004). History of this phytoplasma goes just a little shorter than the history of *Plum pox virus* and its origin can also be found in Southern Europe. This disease was already known in Italy at the beginning of the thirties of the last century under the name of "leptonecrosis" and was recorded there in plum, apricot and cherry (Goidanich 1933, 1934). It was described in Japanese plum for the first time (Goidanich 1933). Almost at the same time, similar disease was described in *P. salicina* and in apricot in Spain, more in detail then was this disease in Spain described by Sanchéz-Capucino and Fournier (1973). During following years, strong outbreaks of this disease in Italy were observed, especially in

Figure 5. Healthy fruits of apricot cv. Harlayne immune to PPV, originated from tree inoculated with PPV (upper row). Malformed fruits of apricot cv. Karola susceptible to PPV, originated from tree inoculated with PPV (lower row) (photo J. Polák)

Figure 6. Tree of apricot infected with ESFY (to the left green healthy tree) (photo J. Polák)

Japanese plum. In France, this phytoplasma was first recorded in the seventies of the last century (Morvan 1977; Desvignes & Cornaggia 1982). In Germany, ESFY was first identified in different species of genus *Prunus* at the beginning of 1990s (Lederer & Seemüller 1992). At the same time, ESFY was also recorded in peach and almond in Germany by different authors and furthermore in Italy (Poggi Pollini *et al*. 1993).

Typical symptoms of ESFY is yellowing and rolling of leaves followed by slower or faster dieback of trees during one or two years. Premature budbreak in winter occurs additionally in Southern Europe. The first occurrence of ESFY in apricot and peach in the Czech Republic was described by Navrátil *et al*. (1998). However, we have already recorded symptoms probably caused by ESFY in apricots and peaches in one orchard of Breeding Station Valtice in the eighties of the last century (Polák & Oukropec unpublished results) and ordered the trees to be eradicated at once. Unfortunately we were not able to identify particles of phytoplasma by means of electron microscopy, neither in phloem of the symptomatic buds, nor in roots of the diseased trees, probably due to the unsuitable term of sample collecting.

Time parallel of distribution and spread of these three mentioned diseases clearly shows connection of climate warming with spread of the smallest plant pathogens, viruses and phytoplasmas, from Southern to the Central Europe and in the Czech Republic from southern to northern parts and from lowlands to highlands and foothills.

In the coming years, in connection with climate warming in the Czech Republic, it is possible to expect invasion and spread of more dangerous warm-requiring viruses, especially vegetable viruses such as *Tomato yellow leaf curl virus* (TYLCV) or *Pepino mosaic virus* (PepMV) and mainly very detrimental viruses of vegetables and other agricultural crops transmitted by whiteflies like *Begomoviruses*, that keep on increasing in their number of species.

Acknowledgements. The author is indebt to Mr. Jiří Svoboda, PhD. and M. Jokeš for support with figure, to Mrs. Ing. Pavla Prášilová for meteorological data and to Mrs. Jitka Pívalová and Miloslava Ducháčová for technical assistance.

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