Folia Forestalia Polonica, series A, 2012, Vol. 54 (1), 42–47

ORIGINAL ARTICLE

The risk of pine wilt disease in Poland

Lidia Sukovata ✉, *Andrzej Kolk, Tomasz Jaworski and Radosław Plewa*

Forest Research Institute, Forest Protection Department, Braci Leśnej 3, Sękocin Stary, 05-090 Raszyn, Poland, phone: +48 22 7153832, fax: +48 22 7150557, e-mail: L.Soukovata@ibles.waw.pl

Abstract

The pine wood nematode (PWN) *Bursaphelenchus xylophilus* (Steiner et Buhrer) Nickle (Aphelenchida, Parasitaphelenchidae), causing the pine wilt disease (PWD), is a quarantine species of Europe that was found in Portugal in 1999. High ambient temperature (above 20° C) is considered to be one of the main factors enhancing the development of PWD in pine stands. In the early 90s of the last century, Poland was considered a country of low risk of PWN establishment. The aim of our study was to verify whether this status has changed due to the effects of climate change. We analysed changes in monthly mean ambient temperatures in June, July and August from 75 weather stations in various regions of Poland from 2005–2010. Additional analyses of changes in monthly mean temperatures in July and August in the period 1991–2010 were performed for the weather station where the highest temperatures were recorded.

Multi-year (2005–2010) average of mean temperatures in June did not exceed 20° C at any of the meteorological stations. However, in July it was higher than the threshold temperature at 26 meteorological stations located in the central part of Poland. The highest multi-year average temperatures were recorded at the station in Koło (52° 12' N, 18° 38' E). A detailed analysis of July and August temperature changes at this station during the period 1991–2010 revealed increasing trends that were described by polynomial functions. The most substantial increase has been observed since 2001. The mean temperature in July and August over the last decade (2001–2010) has increased by 2.4 and 1.5° C respectively when compared to the previous decade.

It is our conclusion that, although the PWN has not yet been found in Poland, the country should no longer be regarded as an area of low risk due to the effects of summer temperature increase. Other factors favourable for the pine wilt disease development and spread were discussed.

Key words

Bursaphelenchus xylophilus, pine wood nematode, infestation risk, pine wilt disease, Poland, temperature, climate change

Introduction

Pine wilt disease (PWD) is caused by the pine wood nematode (PWN) *Bursaphelenchus xylophilus* (Steiner et Buhrer) Nickle (Aphelenchida, Parasitaphelenchidae), a parasitic nematode that develops in the wood of many coniferous species, but mainly in *Pinus* spp. (Kiyohara and Tokushige 1971; Mamiya 1972). The rapid proliferation of the pathogen in a tree results in a disruption of water conductance and eventually causes plant death

Received 22 June 2011 / Accepted 12 October 2011

within several days from the time of infection. PWN is transmitted from infested trees to new hosts by longhorn beetles *Monochamus* Dejean spp. (Coleoptera, Cerambycidae) either during oviposition or maturation feeding (Mamiya and Enda 1972; Wingfield 1983; Linit 1988, 1990; Sousa et al. 2001; Naves et al. 2007a, b).

PWN is native to North America and was accidentally introduced to Japan in the early 20th century; it has spread from there throughout other regions of Asia (Nickle et al. 1981). Although the nematode was placed on the European list of quarantine species (the EPPO A1 list, currently the A2 list – www.eppo.org), it was found in Europe (near Lisbon, Portugal) in 1999 (Mota et al. 1999). There is a very high risk that PWN will expand to new areas within the European continent including Poland, where forests are dominated by Scots pine *Pinus sylvestris* L., a species that is very susceptible to PWN (Final report… 2007). Although a number of surveys have been conducted in the past 15 years, there are no reports that *B. xylophilus* occurs in Poland (Brzeski and Baujard 1997; Filipiak et al. 2007; Karnkowski 2008).

Dieback of pines caused by PWN has been reported only in regions of North America or Japan that are characterised by a warm climate (Evans et al. 1996) where the mean summer ambient temperature exceeds 20° C (Rutherford and Webster 1987). This is the threshold temperature beyond which is considered to be detrimental for tree growth (Rutherford et al. 1990). Additionally, the most intensive swarming of the pine sawyer *Monochamus galloprovincialis* (Oliv.), the main PWN vector in Europe, occurs in the summer months. Thus, high temperature is considered to be one of the main factors determining the successful invasion and colonisation of a tree by the nematode (Final report… 2007). This was confirmed in a series of laboratory studies that were conducted under various temperature conditions. The mortality of Scots pine seedlings that had been inoculated with PWN and were held at temperatures of 20° C and 25° C reached 100% after 60 days, and did not differ significantly, whereas none of the seedlings died at a temperature of 15° C (Final report … 2007).

In the early 90s of the last century, Poland was considered a country of low risk of PWN establishment, because mean August temperatures were lower than 20° C (Evans et al. 1996, ref. to De Guiran and Boulbria 1986). The aim of our study was to verify whether this status has changed due to the effects of temperature change.

Material and methods

Monthly mean ambient temperatures in June, July and August from 75 weather stations in various regions of Poland from 2005–2010 (http://www.tutiempo.net) were analysed in order to identify areas that would be most susceptible to the PWN and where maximum tree mortality would occur if it was to be introduced into Poland. Spatial distribution of average values for the six year period were presented as maps using ArcGIS 9.2. Additional analyses of changes in monthly mean temperatures in July and August in the period 1991–2010 were performed for that weather station where the highest temperatures were recorded. The trend in temperature changes in each of two months was estimated using a linearized regression model (with *Year* as the independent variable and temperature *T* as the dependent variable). The years 1991–2010 were transformed to obtain successive years from 1 to 20. Data were analysed using Statistica 8 software (StatSoft Inc. 2007).

Results

The spatial distribution of the multi-year (2005–2010) average temperatures for June, July and August are presented in Fig. 1. During that period, the average June temperature did not exceed 20° C at any weather station and varied from 14.1 to 18.9° C (Fig. 1). July was found to be the warmest summer month. The multi-year average of monthly temperature ranged from 15.3 to 21.9° C, and exceeded 20° C at 26 weather stations and 21° C at seven stations. Those stations were located mainly in the central part of the country (Fig. 2). In both months, the minimum and maximum values were recorded in Zakopane (in southern Poland, 49° 18' N, 19° 57' E) and Koło (in central Poland, 52° 12' N, 18° 38' E), respectively. Although August appeared to be the second warmest month, the differences in temperature among stations were much smaller than in June and July. The lowest multi-year (2005–2010) average of monthly mean temperatures (17.8° C) was recorded in Piła (53° 08' N, 16° 45' E, and the highest temperature (20° C) occurred in Inowrocław (52° 47' N, 18° 14' E) and Koło (Fig. 3).

An analysis of the changes in monthly mean temperatures in July during the period 1991–2010 at the weather station in Koło (the station with the highest

Fig. 1. Distribution of the multi-year (2005–2010) average of monthly mean temperatures in June based on data from 75 meteorological stations in Poland

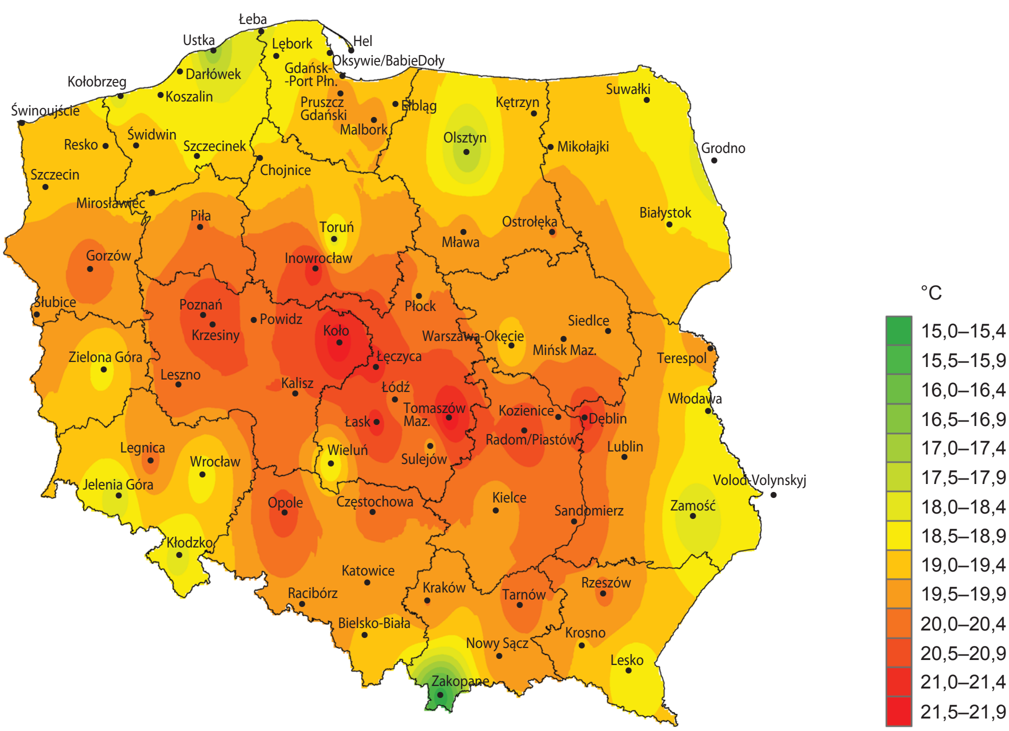

Fig. 2. Distribution of the multi-year (2005–2010) average of monthly mean temperatures in July based on data from 75 meteorological stations in Poland

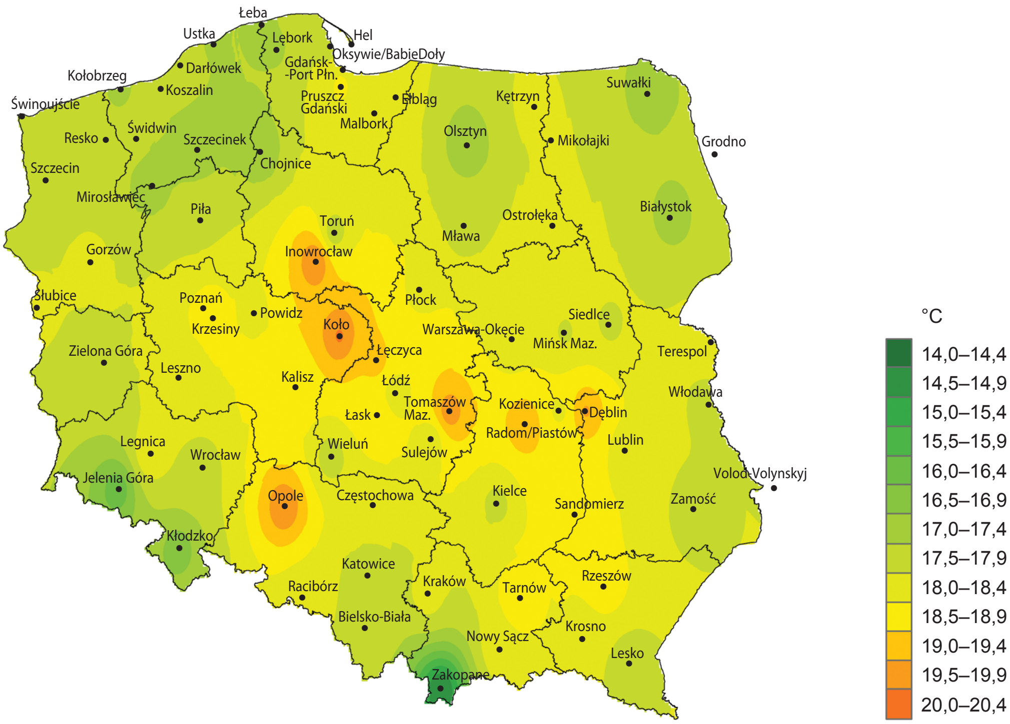

Fig. 3. Distribution of the multi-year (2005–2010) average of monthly mean temperatures in August based on data from 75 meteorological stations in Poland

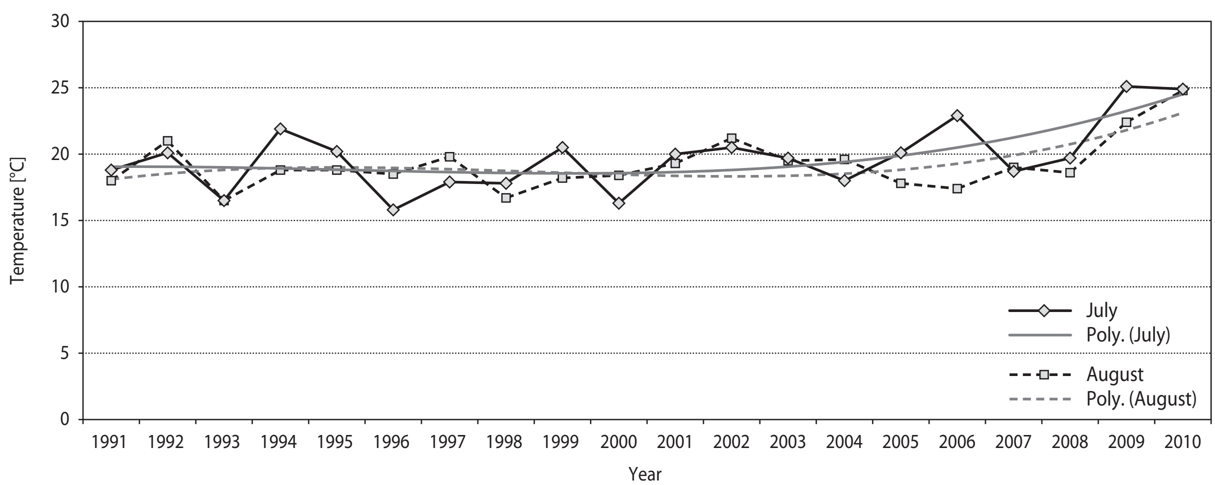

Fig. 4. Monthly mean ambient temperatures in July and August during the period 1991–2010 at the weather station in Koło

summer temperatures) indicates that since 2001 it has not fallen below 18° C, and varied from 18.0 to 25.1° C (Fig. 4). Temperatures above 20° C were recorded in 6 of 10 years. Before 2001, temperatures ranged from 15.8 to 21.9° C and the threshold of 20° C was exceeded on only 4 occasions. The difference between multi-year averages of July monthly mean temperatures during the periods 1991–2000 and 2001–2010 was 2.4° C. The changes have a significant increasing trend that can be described by the third degree polynomial function

$$T = 18.34 + 0.00065 \times Year^3 \quad [1]$$

($R^2 = 0.41$ $F = 12.49$ df = 1,18 $P = 0.0024$) with "*Year*" and "*Year*^{2}" being insignificant.

The annual variation in August monthly mean temperatures was not as large as that recorded in July, but the trend is also increasing

$$T = 18.25 + 0.00044 \times Year^3 \quad [2]$$

($R^2 = 0.31$, $F = 8.18$, df = 1,18, $P = 0.0104$).

Very high temperatures of 25.1 and 24.9° C recorded in 2009 and 2010 respectively are particularly noteworthy (Fig. 4). During the last decade, the mean temperature exceeded 20° C on three occasions, whereas during the previous decade it occurred only once. The multi-year average of August monthly mean temperatures in 2001–2010 increased by 1.5° C when compared to the same period in 1991–2000.

Discussion

An analysis of data from 75 weather stations indicates that the central part of Poland is the warmest region of the country during the summer months. The mean July and August temperatures in 2005–2010 exceeded 20° C, which is considered to be the temperature threshold favourable for the development of PWN.

Earlier simulations (Evans et al. 1996, ref. to De Guiran and Boulbria 1986) based on August isotherms in Europe excluded Poland from the regions where it was suggested that PWN could establish and spread. However, the multi-year mean summer temperatures in 2001–2010 have increased considerably in comparison to the period 1991–2000 (by 2.4° C and 1.5° C in July and August, respectively, at the weather station in Koło). This provides evidence that suggests that the climate in Poland is warming. Summer temperatures in the central part of the country are sufficient to support pine wilt in susceptible trees. According to the Hadley Centre transient climate change experiment (Evans et al. 1996 ref. to Hadley Centre 1992) and the IPCC report of 2007 (IPCC 2007), both an increase in summer temperatures and an increased frequency of droughts is predicted for central and eastern Europe. If these predictions are even moderately accurate, the entire area of pine forests in Poland may soon be considered favourable to the establishment and rapid spread of PWN.

In addition to favourable environmental factors such as high temperature and low precipitation, poor site conditions and high tree density, conditions that increase intraspecies competition, are key factors that contribute to weakening of trees (Final report... 2007). Consequently, implementation of appropriate silvicultural treatments (e.g. thinning) will be critical. In addition, the population density of the pine sawyer, a vector of PWN, should be managed at a low level. This can be facilitated by promptly removing trees felled during silvicultural treatments, and all other woody material that is considered suitable for breeding of pine sawyer adults as such as upper portions of crowns, branches larger than 1,5 cm in diameter, and dead wood already infested by the pine sawyer. These practices should be implemented particularly in those regions of Poland that have been identified as high risk for PWN establishment.

It is our conclusion that, although the PWN has not yet been found in Poland, the country should no longer be regarded as an area of low risk due to the increased summer temperatures. The potential risk of infestation based on the distribution of multi-year average temperature in July can be used to improve national surveys for the PWN. A stratified sampling design can be implemented and more intensive sampling should be conducted in the central part of the country.

Acknowledgements

The authors wish to thank G. Tarwacki for his assistance in creating maps of temperature distribution. We are grateful to Mike McManus and G. Keith Douce for editing manuscript. The study was conducted within the framework of the project financed by the Polish National Fund for Environmental Protection and Water Management at the request of the Minister of the Environment.

References

Brzeski M.W., Baujard P. 1997. Morphology and morphometrics of *Bursaphelenchus* (Nematoda: Aphelenchoididae) species from pine wood of Poland. *Annales Zoologici*, 47 (3/4), 305–319.

Evans H.F., McNamara D.G., Braasch H., Chadoeuf J., Magnusson C. 1996. PEST Risk Analysis (PRA) for the territories of the European Union (as PRA area) on *Bursaphelenchus xylophilus* and its vectors in the genus *Monochamus*. *Bulletin OEPP/EPPO*, 26, 199–249.

Filipiak A., Jakubowska A., Tomalak M. 2007. Utility of individual specimens for taxonomic identification of a quarantine nematode, *Bursaphelenchus xylophilus* (in Polish with English summary). *Progress in Plant Protection*, 47 (1), 222–227.

Final report, 2007. PHRAME – Plant Health Risk and Monitoring Evaluation. EU funded project, QLK5-CT-2002-00672: Development of improved pest risk analysis technique for quarantine pests, using pinewood nematode, *Bursaphelenchus xylophilus*, in Portugal as a model system – www.forestry.gov.uk/pdf/PHRAMEJuly07.pdf/$FILE/PHRAMEJuly07.pdf

IPCC 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (eds.: S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 996.

Karnkowski W. 2008. Official survey for *Bursaphelenchus xylophilus* carried out on the territory of the Republic of Poland. In: Pine Wilt Disease: A Worldwide Threat to Forest Ecosystems (eds.: M.M. Mota and P. Vieira). Springer, Netherlands, 75–81.

Kiyohara T., Tokushige Y. 1971. Inoculation experiments of a nematode, *Bursaphelenchus* sp., onto pine trees (in Japanese with English summary). *Journal of Japanese Forestry Society*, 51, 193–195.

Linit M.J. 1988. Nematode-vector relationships in the pine wilt disease system. *Journal of Nematology*, 20, 227–235.

Linit M.J. 1990. Transmission of pinewood nematode through feeding wounds of *Monochamus carolinensis* (Coleoptera: Cerambycidae). *Journal of Nematology*, 22, 231–236.

Mamiya Y. 1972. Pine wood nematode, *Bursaphelenchus lignicolus* Mamiya and Kiyohara, as a causal agent of pine wilting disease. *Review of Plant Protection Research*, 5, 46–60.

Mamiya Y., Enda N. 1972. Transmission of *Bursaphelenchus lignicolus* (Nematoda: Aphelenchoididae) by *Monochamus alternatus* (Coleoptera: Cerambycidae). *Nematologica*, 18, 159–162.

Mota M.M., Braasch H., Bravo M.A., Penas A.C., Burgermeister W., Metge K., Sousa E. 1999. First report of *Bursaphelenchus xylophilu*s in Portugal and in Europe. *Nematology*, 1 (7/8), 727–734.

Naves P.M., Camacho S., de Sousa E.M., Quartau J.A. 2007a. Transmission of the pine wood nematode *Bursaphelenchus xylophilus* through feeding activity of *Monochamus galloprovincialis* (Col., Cerambycidae). *Journal of Applied Entomology*, 131(1), 21–25.

Naves P.M., Camacho S., Sousa E., Quartau J.A. 2007b. Transmission of the pine wood nematode *Bursaphelenchus xylophilus* through oviposition activity of *Monochamus galloprovincialis* (Coleoptera: Cerambycidae). *Entomologica Fennica*, 18, 193–198.

Nickle W.R., Golden A.M., Mamiya Y., Wregin W.P. 1981. On the taxonomy and morphology of the pine wood nematode, *Bursaphelenchus xylophilus* (Steiner & Buhrer 1934) Nickle 1970. *Journal of Nematology*, 13, 385–392.

Rutherford T.A., Webster J.M. 1987. Distribution of pine wilt disease with respect to temperature in North America, Japan, and Europe. *Canadian Journal of Forest Research*, 17, 1050–1059.

Rutherford T.A., Mamiya Y., Webster J.M. 1990. Nematode-induced pine wilt disease: factors influencing its occurrence and distribution. *Forest Science*, 36, 145–155.

Sousa E., Bravo M., Pires J., Naves P., Penas A., Bonifácio L., Mota M. 2001. *Bursaphelenchus xylophilus* (Nematoda: Aphelenchoididae) associated with *Monochamus galloprovincialis* (Coleoptera: Cerambycidae) in Portugal. *Nematology*, 3, 89–91.

StatSoft, Inc. 2007. STATISTICA (data analysis software system), version 8.0. www.statsoft.com.

Wingfield M. 1983. Transmission of pine wood nematode to cut timber and girdled trees. *Plant Disease*, 67, 35–37.