Anthropogenic pathways in the spread of the pinewood nematode and predictions of future expansion

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1- INTRODUCTION

The pinewood nematode (Fig. 1a), *Bursaphelenchus xylophilus* (Steiner & Buhrer) Nickle, is the causal agent of the pine wilt disease. This pest originating in North America has invaded many countries in the world, especially in Asia and in Europe recently. In its native range it does not affect considerably *Pinus* health, whereas in the invaded range, it causes dramatic damage in pine stands (Fig 1b). Transmission by insect vectors of the genus *Monochamus* (Fig. 1c) is the primary means of local dispersal but human mediated dispersal is suspected to play an important role in long distance jumps. Therefore, we have studied long-distance dispersal based on the invasion history in China and developped a spread model. Then we have applied this model to Europe to predict the invasion risk.

Fig. 1: (a) pinewood nematode, (b) trees killed by the pinewilt disease, (c) carrier beetle

2- ANALYSIS OF SPREAD IN CHINA

(A) Local spread of pinewilt disease

The pinewilt disease spread at a constant speed of 7.5 km/year around the first invaded site (Nanjing) during 5 years, and then the spread burst and no clear pattern was observed (Fig. 2; Robinet et al. 2009).

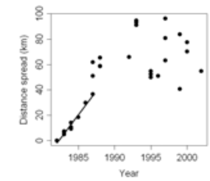

Fig. 2. Spread from the 1st invaded site

(B) Long distance dispersal of pinewilt disease

Infested sites located at more than 7.5 km from the nearest infested site were considered to be the result of a long-distance jump. The mean number of new infestations per year was equal to 3.4 during 1982-2000, and 18.2 during 2001-2005. The mean long-distance dispersal was estimated to 111-339 km. Railways, river ports and lakes had significant effects of the spread pattern, and human population density (indicator of the risk for accidental transportation) explained a large part of the invasion probability (Fig. 3; Robinet et al. 2009).

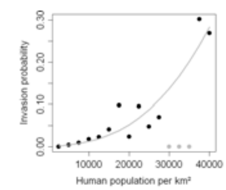

Fig. 3. Role of human population density of the invasion probability

3- MODELLING THE INVASION RISK IN CHINA

Based on climatic thresholds for the carrier beetle (mean temperature in July above 21.3°C and mean temperature in January above -10°C; Ma et al. 2006), we determined area where the climate was suitable (Fig. 4A). The potential area could expand by 40% with a 3°C warming (Fig. 4B).

Then we have developped a spread model combining climatic suitability, local dispersal and long-distance dispersal. This individual based model was stochastic and we made 300 replicate simulations to calculate the probability of invasion in each grid cell in 2025.

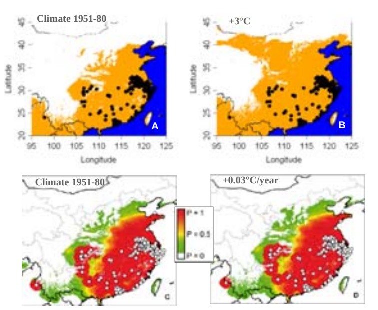

Fig. 4. Potential distribution of the pinewilt disease. A and B: orange color represents the area where the climate is suitable in case of a stable climate (A), and a 3°C warming (B). C and D: invasion risk in 2025 predicted by the spread model in case of a stable climate (C), or a warming (D).

The model predicted an expansion of the potential invasion area (defined by P>0) by 47% in 2025 under a stable climate (Fig. 4C), and by 55% under an increase of 0.03°C per year (Fig. 4D; Robinet et al. 2009).

4- MODELLING THE INVASION RISK IN PORTUGAL

The pinewilt disease was discovered in Portugal in 1999. Despite containment measures immediately applied, the disease has expanded over all the country and the European authorities are worried about the risk of expansion. To provide a first estimate of the invasion risk, we have applied the spread model initially developped for China. However caution is needed because the parameters should be estimated in Europe as soon as appropriate data are available. For instance, the carrier beetle is not exactly the same species in Asia and in Portugal, and flying capabilities should be carefully determined to improve the model.

Based on the temperature threshold for the disease expression (mean temperature in July above 20°C), 27% of the study area would be favorable in case of a stable climate (1979-2008 normal; Fig. 5A) and this area could expand by 129% in case of a 3°C warming (Fig. 5B).

We have included the pine trees distribution in the spread model previously developped for China. The potential invasion area (defined by P>0) could cover 6% of the study area in 2025 under a stable climate (Fig. 5C), and 12% under a stochastic increase of 0.06°C per year ± 0.81 (following yearly fluctuation observed in the past in Europe) (Fig. 5D; Robinet et al. in prep).

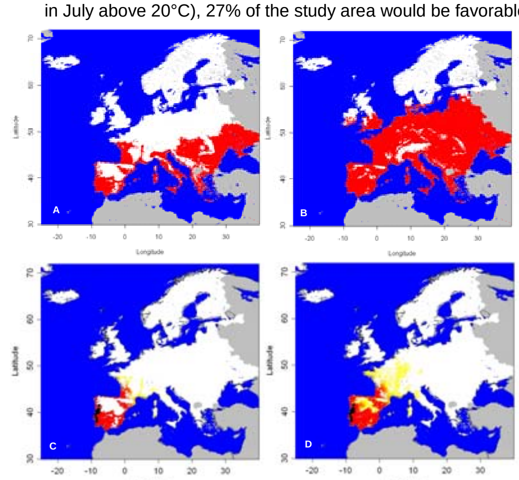

Fig. 5. Potential distribution of the pinewilt disease. A and B: red color represents the area where the climate is suitable in case of a stable climate (A), and a 3°C warming (B). C and D: invasion risk in 2025 predicted by the spread model in case of a stable climate (C), or a stochastic warming (D).

5- DISCUSSION AND CONCLUSION

The pinewilt disease is expanding very quickly all around the world and no efficient control tool is currently available. There is a urgent need to understand the mechanism of spread and the climatic constraints of the potential carrier beetles, of the pinewood nematode and of the disease to determine more accurately the invasion risk and provide reliable predictions for decision makers. Although the pinewilt disease is not considered as an important pest in North America, it is worth collecting and exploring data to understand why the disease appears quite rarely there.

This spread model is a preliminary model of dispersal taking into account the human mediated dispersal which is an important factor in the spread of many pests. This model could be combined to other models already developped, e.g. a model describing the disease transmission at a stand scale (Yoshimura et al. 1999), or a model describing the tree susceptibility (EU project PHRAME).

References

Ma R-Y, Hao S-G, Kong W-N, Sun J-H, Kang L (2006) Cold hardiness as a factor for assessing the potential distribution of the Japanese pine sawyer *Monochamus alternatus* (Coleoptera: Cerambycidae). Ann For Sci 63: 449–456.

Robinet C, Roques A, Pan H, Fang G, Ye J, Zhang Y & Sun J (2009) Role of human-mediate dispersal in the spread of the pinewood nematode in China. PLoS ONE 4(2): e4646. doi:10.1371/journal.pone.0004646

Robinet C, Van Opstal N, Baker R, Tröltzsch K & Roques A. Invasion risk of the pinewilt disease in Europe under various scenarios of climate warming and human transportation. In preparation.

Yoshimura A, Kawasaki K, Takasu F, Togashi K, Futai K, et al. (1999) Modeling the spread of pine wilt disease caused by nematodes with pine sawyers as vector. Ecology 80: 1691–1702.

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