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Swedish University of Agricultural Sciences

SLU Risk Assessment of Plant Pests

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Potential establishment of the priority pest *Popillia japonica* in Sweden

Background and terms of reference

The European Commission has established a list of 20 priority pests (Commission Delegated regulation (EU) 2019/1702). The pests have been selected among the Union quarantine pests as the pests for which the potential economic, environmental and social impact is assessed to be the most severe in the EU.

For each priority pest Member States shall carry out annual surveys (article 24 in EU regulation 2016/2031). However, the regulation further states that:

“The surveys shall not be required to be carried out for pests for which it is unequivocally concluded that they cannot become established or spread in the Member State concerned due to its ecoclimatic conditions or to the absence of the host species.”

For some of the priority pests it is currently uncertain whether the ecoclimatic conditions or host availability in Sweden allow their establishment in whole or part of the country.

The Swedish Board of Agriculture has requested SLU Risk Assessment of Plant Pests to assess whether certain priority pests are able to establish in Sweden and further, when relevant, identify the area of potential establishment. This report provides the assessment of the potential establishment of *Popillia japonica* (EPPO code: POPIJA).

Short description of *Popillia japonica*

Popillia japonica (Japanese beetle) is an extremely polyphagous pest. The adult beetles feed on foliage, flowers, and fruits whereas the larvae primarily feed on roots of grasses (thereby destroying the turf in lawns, parks and golf courses). The beetle is native in northern Japan and in the far east of Russia but is currently also found widely distributed in North America (EPPO 2020). It is also present in the EU, in Portugal (some islands of the Azores) and northern Italy (Lombardy: Varese and Milano, and Piedmont: Novara), but it is not widely distributed and under official control (EFSA 2019a). *Popillia japonica* is also present in Switzerland but under eradication (EPPO 2020). Further, it has been found in two locations in Germany (Urban 2018; 2019).

A short description of the lifecycle is as follows (EFSA, 2018 and references therein); adults emerge during summer, spend some time for maturation feeding and thereafter mate. Eggs are laid in the soil in the upper 10 cm and larvae go through three instar stages. The third instar overwinters deeper in the soil and move upwards during spring to pupate. One life cycle may take 1 or 2 years depending on the temperature (Clausen et al. 1927, Vittum 1986).

Presence of hosts

Host plants are present all over Sweden. The beetle has been observed feeding on at least 259 species of plants and economic damage has been recorded on more than 100 species (CABI 2019, Fleming 1972). It is well known as a pest of turfgrass and fruit trees. Hosts relevant for Sweden includes for example tree species belonging to *Malus* and *Prunus* and shrubs such as *Rosa* and *Rubus* (EFSA, 2019b). It is likely that more host plants will be added to the host list considering that the host range in North America appears to be larger than in the beetles native area (CABI 2019).

Ecoclimatic conditions

Popillia japonica appears to have a high capacity to adapt to new climatic conditions since the current area of establishment includes areas with considerably different climatic conditions than those in the areas where the beetle is native (CABI 2019). Zhu et al. (2017) show that the native Japanese populations and non-native North American populations do not occupy the same climate space and concludes that there is suitable climatic space that remains unoccupied in North America.

To determine if *P. japonica* is established in Köppen-Geiger climate zones which are found in Sweden we mainly used data from a recent review of the worldwide observations of established populations provided by Kistner-Thomas et al. (2019) and plotted them on a map with Köppen-Geiger climate zones (Beck et al. (2018) using climate data for the time period 1980-2016) (Appendix 1; Table 1). The results showed that there are plenty of established populations of *P. japonica* in the climate zone Dfb (cold, no dry season, warm summer) both in USA, Canada and Japan. Climate zone Dfb is found in the southern part of Sweden (blue colored area in Figure 1). There was however no established populations in climate zone Dfc (Cold (continental) without dry season, cold summer) which is found in the part of Sweden north of the Dfb zone (dark green colored area in Figure 1).

Ecological niche modeling, where anthropogenic variables also were incorporated, has been used to predict areas of invasion of *P. japonica* (Zhu et al. 2017). Four climatic variables were included, i.e. annual mean temperature, precipation of the wettest month, precipitation of the driest month, and a moisture index. The anthropogenic variables that were included were human footprint, human population density and two land cover classes, i.e. managed vegetation and urban/built-up (for Sweden, however, the impact of anthropogenic factors appear to be small). The result for Sweden is shown in Figure 1.

Very recently the bioclimatic niche model CLIMEX was used to predict the potential global distribution of *P. japonica* (Kistner-Thomas 2019). For the analysis a 1981–2010 global climatological data parameter set was used including temperature, a threshold for annual heat sum, moisture, cold stress, heat stress, dry stress, and hot-wet stress. The model predicts that the climatic conditions are suitable for establishment in southern parts of Sweden (see Figure 1).

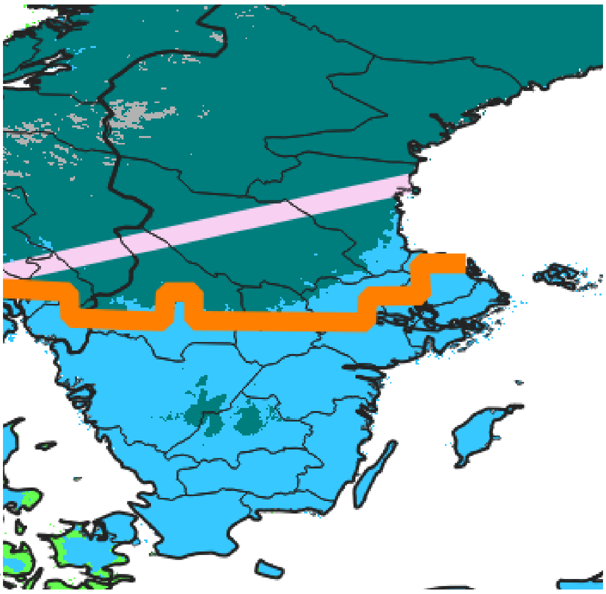

Figure 1. *The blue color depicts the Köppen-Geiger climate zone Dfb which is a climate zone where* Popillia japonica *has been able to establish populations elsewhere (1980-2016; modified map from Beck et al. 2018; www.gloh2o.org/koppen; available under the CC BY-NC 4.0 license). The orange line represents the northern limit according to a recent CLIMEX analysis by Kistner-Thomas (2019). The pink line depicts a crude estimation of the northern limit above which the area is classified to be in the lowest suitability class according to an ecological niche modeling approach where antrophogenic variables were incorporated by Zhu et al. (2017). The map of the counties in Sweden is from SCB (2020).*

The area of potential establishment in EU has recently been estimated by EFSA based on accumulated day degrees both in a Pest Report and in a Pest Survey Card (EFSA 2019a, EFSA 2019b). They used the same approach as the analysis by Korycinska et al. (2015), where the requirement of 1422 degree days, above a threshold of 10°C, were used for the development from egg to egg. They then assumed that the yearly requirement for a two-year life cycle is half of that, i.e. 711 degree days. Information relevant for this assumption is provided in Jarošík et al. (2011). It should be noted that a map in the published version of EFSAs Pest survey card on *P. japonica* is based on temperature data from 1998-2008 and thereby show different results (S. Vos., Personal communication). In the updated version of the survey card, i.e. in the “Story map for survey of *Popillia japonica*”, the map has been replaced with a map based on temperature data from 1998-2017 (EFSA 2020). The area in Sweden where the requirement of 711 accumulated degree days for establishment are not reached, based on temperature data from 1998-2017, is shown in Figure 2.

The importance of soil humidity for the establishment of *P. japonica* is frequently emphasized in litterature since newly hatched larva cannot survive desiccation (Bourke 1961, Kistner-Thomas 2019). In the Pest survey card of *P. japonica* EFSA (2019a) suggests that the degree day requirement should be combined with the humidity requirement to make a better prediction of the potential for establishment. We have here implemented that approach (Figure 2). The red colour depict the areas where the accumulated degree days does not reach 711, i.e. the areas where the temperature is assumed not to favour successful development of *P. japonica* (EFSA 2019b). It should, however, be noted that since mean values are used in the figure the accumulated degree days frequently does not reach 711 for individual years which decrease the likelihood of establishment for a large part of this area (Appendix 2). The green-blue to blue colour in Figure 2 indicates areas where more than 250 mm of rain on average is projected to fall during the summer, i.e. areas that would fullfill the soil moisture requirement of *P. japonica* (Fleming 1972). However, *P. japonica* may also establish in areas with slightly lower soil humidity considering the establishment reported in Milan where the summer rainfall only reach 234 mm on average (EFSA 2019b). In Sweden, the soil moisture conditions appear to become most suitable for establishment in Halland (Figure 2).

Further, a mean summer temperature in the range 17.5 - 27.5 °C is considered necessary for successful egg hatching and early larval development and there is a good match between these criteria and the distribution in North America (Korycinska et al. 2015). The areas predicted to be unsuitable for establishment in Sweden based on mean summer temperatures are in general agreement with the other predictions described above (Appendix 1; Figure 1 vs Figure 1 and 2).

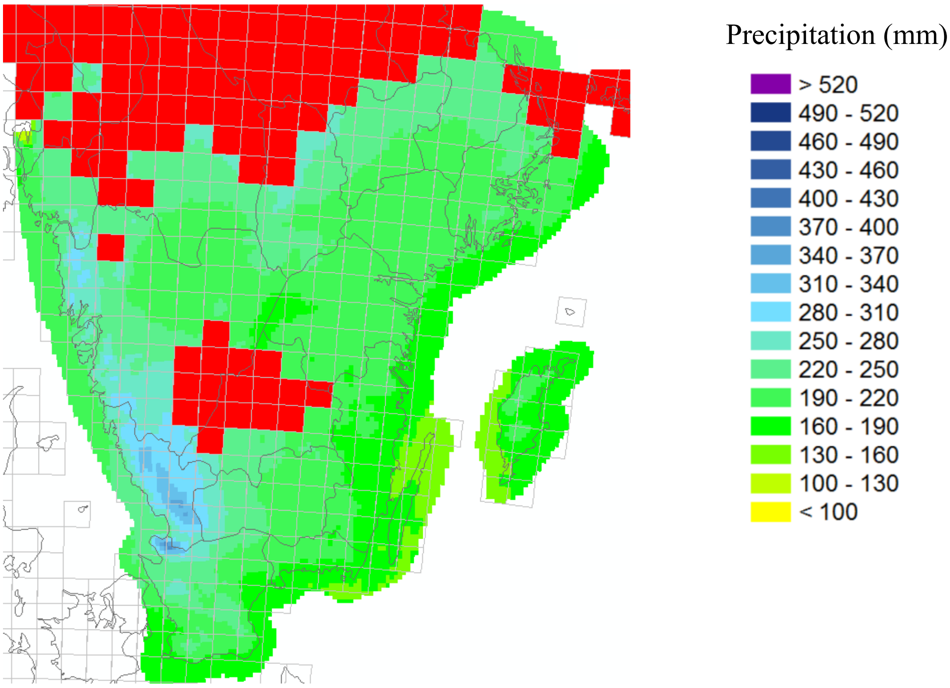

Figure 2. *Red colour represents areas where the requirement of 711 accumulated degree days for establishment are not reached (Korycinska et al. 2015). The green-blue to blue colour indicate areas where more than the minimum requirement of 250 mm of rain on average falls during the summer (Fleming 1972). County borders are depicted with black lines. Data for accumulated degree days above a threshold of 10°C are from EFSA (2019b) and based on temperature data from the time period 1997-2017. The data on precipation are from SMHI (2020) and refers to a prediction for the average precipitation and temperature during summer, i.e. June, July and August, for the period 2021-2050 using the RCP 4.5 scenario.*

Establishment in greenhouses

According to Korycinska et al. (2015) it is unlikely, with medium confidence, that *P. japonica* can establish in greenhouses. There are no records of multiple generations per year and in order to be able to complete their development the larvae may require a period with cold temperatures. Further, although there are some old records of *P. japonica* causing damage in greenhouses there is no support for that those populations were established. No recent records of damage in protected environments were found. Accordingly, in a recent publication it is stated that *P. japonica* is generally not considered to be a pest of plants grown in protected cultivation (EFSA 2018).

Conclusion

Based on the information presented above our assessment is that hosts are available and that the ecoclimatic conditions are suitable for establishment of *P. japonica* in Sweden. The uncertainty of this conclusion was assessed to be low. All predictions based on recent climate data predicts that the southern part of Sweden is suitable and the predictions of the northern limit for establishment is also rather persistent, i.e. around *Limes Norrlandicus.* Surveys may focus on areas where the soil moisture conditions are most suitable for establishment, e.g. areas in the county Halland.

Establishment in greenhouses were assessed to be unlikely with medium uncertainty, which is in accordance with a previous assessment by Korycinska et al. (2015).

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Appendix 1

Table 1. Some examples of established populations of *Popillia japonica* in Köppen-Geiger climate zone Dfb. Based on climate zones estimated using climate data during the time period 1980-2016 from Beck et al. (2018).

Location	**Reference**
Fort Erie, south east of Ontario	Bourke 1961
Port Burwell, south east of Ontario	Bourke 1961
Halifax, Nova Scotia	Bourke 1961
Belleville, Ontario	Allsopp 1996
Ganonoque, Ontario	Allsopp 1996
Several other locations	Kistner-Thomas 2019

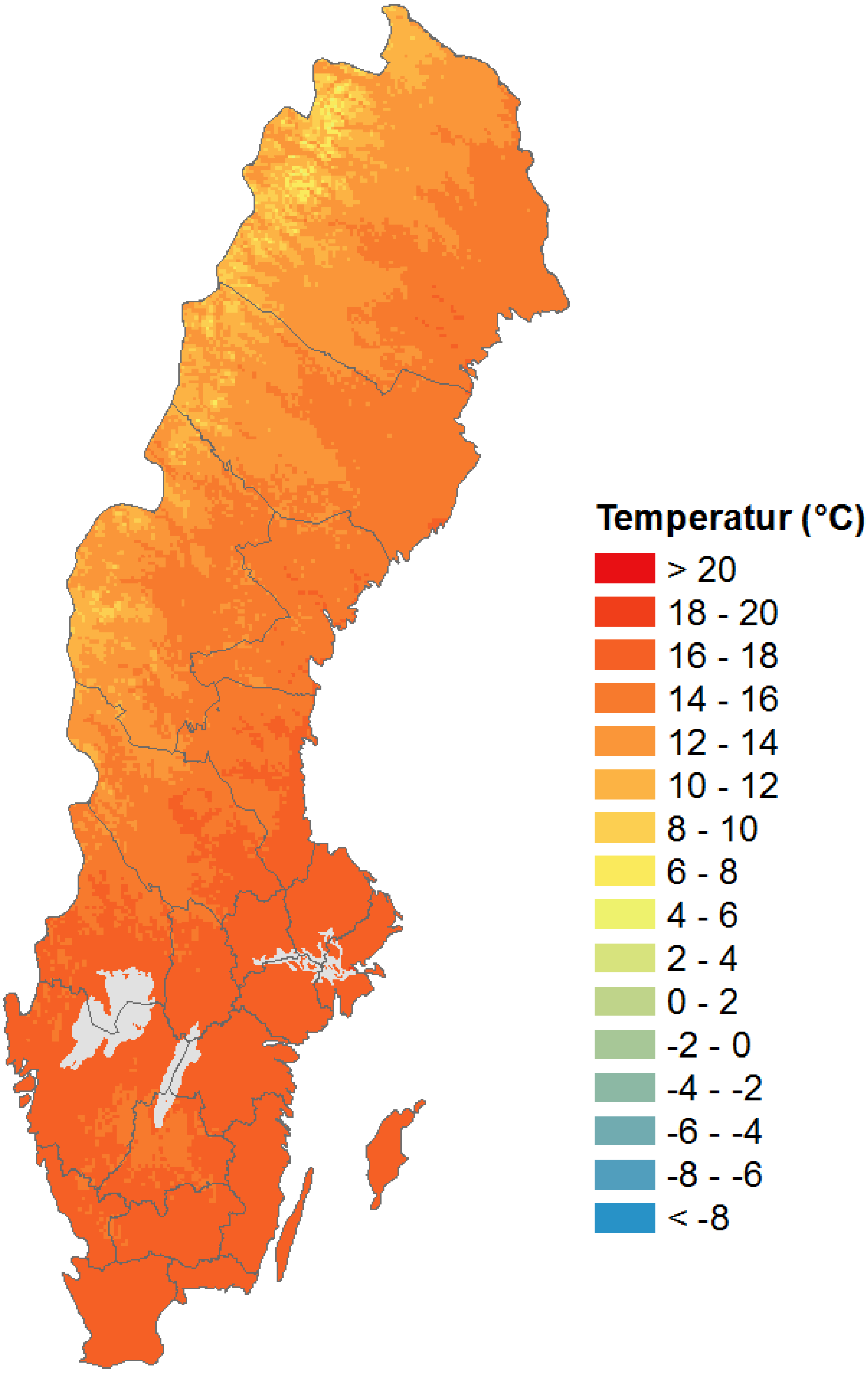

Figure 1. Areas in dark orange to red represent areas where the mean temperature in June, July and August is ≥17.5°C and thus considered suitable for the early stages of Popillia japonica *(Korycinska et al. 2015). County borders are depicted with black lines. The figure is from SMHI (2020) and shows a prediction for the average temperature during summer, i.e. June, July and August, for the period 2021-2050 using the RCP 4.5 scenario .*

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Appendix 2

Thermal requirements for development

Thermal requirements to complete one generation (i.e. egg to egg) of *P. japonica* has been estimated to 1422 DD above a threshold of 10°C (Régnière et al. 1981; Jarošík 2011). A two-year cycle is observed in some regions and it has then been assumed that an annual 711 DD above 10°C would be required per year (Jarošík 2011; Korycinska et al. 2015; EFSA, 2019).

Whether these presumed temperature requirements for development were met in Sweden was here analysed using the R code by Korycinska (2020) and gridded MARS-AGRI4CAST temperature data for the time period 1999-2018 from JRC (JRC, 2020). Calculations were run in R and maps were created with qGIS (R Core Team, 2019; QGIS Development Team, 2020).

In Sweden the area with mean annual degree days above 711 are found in the southern parts (Figure 1a). Note that these are mean values for the 20-year period and for individual years, values may be higher or lower. The R code from Korycinska (2020) also provides the maximum number of consecutive years when the temperature accumulation is above the threshold. Visualizing these data on a map of Sweden show that a large part of the suitable area identified with the annual mean has time periods when the requirements are not met (Figure 1b).

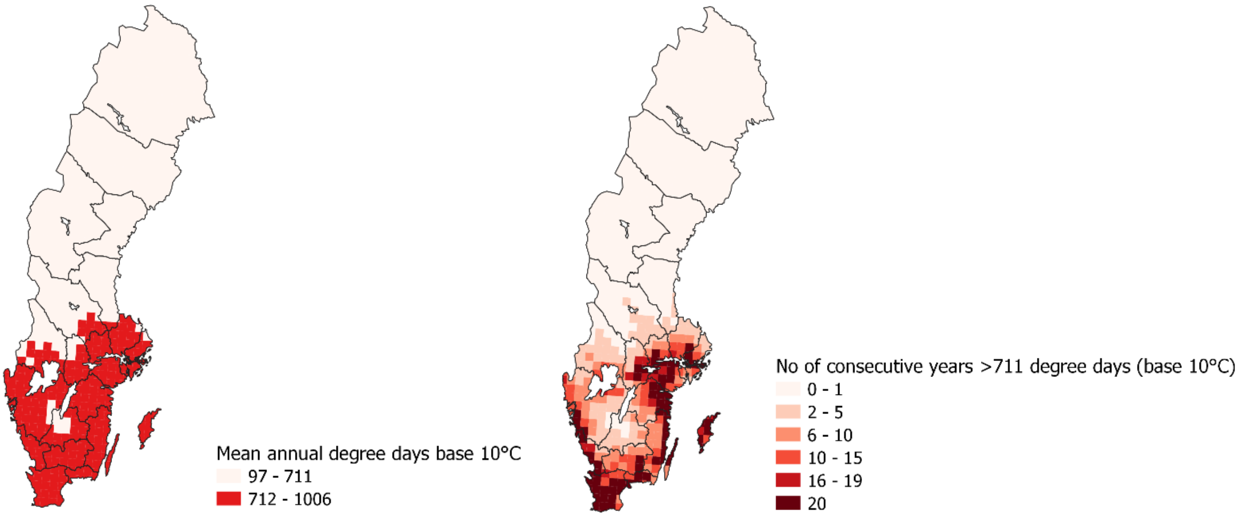

Figure 1. *Mean annual degree days above 10°C with a threshold of 711 DD for the development of* P. japonica *during a 2-year life cycle (a) and number of consecutive years above the thresholds for each grid cell (b). Map of the Swedish counties are from SCB (2020).*

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