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ORIGINAL PAPER

Pest risk analysis of *Metcalfa pruinosa* in Austria

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Abstract The North American planthopper *Metcalfa pruinosa* (Say, 1830) (Hemiptera: Flatidae) was accidentally introduced into Europe, and subsequently caused economic damage to orchards and vineyards in some South-European countries. In 2003, a mass occurrence of *M. pruinosa* was discovered in Vienna, followed by new infestations of several sites. A Pest Risk Analysis was conducted, according to the European and Mediterranean Plant Protection Organization decision support scheme for quarantine pests, to evaluate the risk to Austrian agriculture by *M. pruinosa*. The highest risk of further introduction into Austria arises from trade of deciduous plants infested with *M. pruinosa* eggs from Italy and France where this pest is common and which are important trading partners of Austria. Entry by vehicle traffic is considered moderately likely. Active spread by flight of adult *M. pruinosa* is considered significant only for local dispersal. The CLIMEX® program was applied to predict *M. pruinosa's* potential geographical distribution and to identify areas at risk. In Austria, southern Burgenland and south-east Styria as well as parts of Vienna, Lower and Upper Austria provide the most suitable climate for *M. pruinosa's* development. Organic production areas in theses regions are especially at risk of being damaged. To prevent economic impact and for long-term control of *M. pruinosa*, biological control with its natural enemy *Neodryinus typhlocybae* (Ashmead 1893) (Hymenoptera: Dryinidae) is recommended.

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Introduction

The planthopper *Metcalfa pruinosa* (Say, 1830) (Hemiptera: Flatidae) was accidentally introduced from North America into Italy in 1979 (Zangheri and Donadini 1980), rapidly spread and is currently present in 15 European countries (Strauss 2009). *M. pruinosa* is a polyphagous and gregarious species (Duso and Pavan 1987) that feeds on a wide variety of trees, shrubs and herbs (Bagnoli and Lucchi 2000). Heavy infestations of nymphs cause stunting of shoots, and particularly herbs can seriously be affected and wilt. In Italy, the quality of grapes (sugar content and acidity) was negatively affected through the sucking activity of the nymphs. Serious quantitative damage (30–40% crop loss) on soyabean (*Glycine max* L.) was recorded by Ciampolini et al. (1987). The most severe damage is caused by *M. pruinosa's* honeydew secretions, a substrate of black sooty mould, which leads to a reduced fruit quality (Della Giustina and Navarro 1993). Quality of ornamentals is affected by the wax filaments of the nymphs and the nymphs themselves which make the plants look unpleasant. Plants have to be cleaned as otherwise customers may be reluctant to buy.

In Austria, the first mass occurrence of *M. pruinosa* was discovered in Vienna in 2003. Since then, *M. pruinosa* has expanded its range and new infestation sites have been found in Vienna and Graz (Kahrer et al. 2009). The present study aims to evaluate the pest risk of *M. pruinosa* to Austrian viticulture, fruit-growing and horticulture as it is presumed that it will continue to spread and may threaten organic and integrated production systems. The European and Mediterranean Plant Protection Organization (EPPO) decision support scheme for quarantine pests PM 5/3 (3) was used to estimate the potential of entry, establishment and spread as well as the economic significance in Austria, which is the pest risk assessment (PRA) area (EPPO 2007). In this study, a climate suitability analysis using the CLIMEX® model was carried out to assess the potential distribution of *M. pruinosa* in Austria and to identify areas at risk of an invasion. *M. pruinosa* has a high capacity for spatial dispersal by natural means and different human-mediated pathways. Thus, it is likely that the pest will expand its range and infest cultivated land. A management strategy is warranted to contain the pest to its current restricted distribution.

Materials and methods

The pest risk analysis was conducted following the EPPO decision support scheme for quarantine pests PM 5/3 (3) (EPPO 2007), which provides detailed instructions for analyzing the probability of entry, establishment, spread and assessment of potential economic consequences. To identify means of entry of *M. pruinosa* (pathway analysis), statistical data taken from trade, transport and travel habits were evaluated, as well as the occurrence of the pest and control measures applied in different countries. The assessment of the economic impact of *M. pruinosa* was based on Austrian agriculture production data.

The CLIMEX model

The potential geographical distribution of *M. pruinosa* in Austria was predicted by using the Compare Locations (one species) model of the simulation model CLIMEX® (version 2.0) (Sutherst et al. 2004). CLIMEX® is a modelling tool to estimate the potential distribution and relative abundance of species on the assumption that all other non-climatic constraints are absent (Sutherst and Maywald 1985). CLIMEX® uses an annual growth index (GI) and four stress indices (cold, dry, hot and wet) to calculate an ecoclimatic index (EI), which indicates the overall climatic suitability of a location for permanent occupation by a species. The EI is scaled from 0 (no persistence) to 100 (maximal population size in relation to climate alone) and implies that naturalization is only possible when the value exceeds zero. CLIMEX® parameter values describing *M. pruinosa's* response to climate were estimated via inference from its occurrence in North America, using climate data from locations where *M. pruinosa* is established (Sutherst 2003). Information about the distribution of *M. pruinosa* was obtained from scientific literature, various databases (DAISIE, EPPO reporting Service) and personal communication. Parameters were tested and adjusted in an iterative process until the model closely fitted the current distribution pattern in North America (Table 1). The EI values were imported to a geographical information system (ArcGIS, Vers. 9.3) to create thematic maps (resolution: 30′ longitude/latitude Fig. 2 and 10′ longitude/latitude Fig. 3).

Present distribution of *M. pruinosa*

In North America, *M. pruinosa* possesses an extensive distribution in different climatic zones reaching from Texas and Florida throughout the eastern part of the USA to southern Ontario and Quebec in Canada (Fig. 1; M. Olmi, pers. comm. 2007). It is also present in Bermuda. According to Wilson and Lucchi (2000), the records from California, Mexico, Puerto Rico, Cuba, Jamaica and Brazil are unreliable, because the above records were not based on the study of the male genitalia. This species has not been recorded from the Pacific Northwest or the northern prairies. In Europe, *M. pruinosa* has become established in Italy, southern France (Della Giustina 1986), Slovenia (Sivic 1991), Switzerland (Jermini et al. 1995), Croatia (Maceljski et al. 1995), Austria (Kahrer and Moosbeckhofer 2003), Greece (Drosopoulos et al. 2004), Spain (Pons et al. 2002), Serbia and Montenegro (Hrncic 2003), Hungary (Orosz and Dèr 2004), Bulgaria (Tomov et al. 2006), Turkey (Karsavuran and Güçlü 2004), Bosnia Herzegovina (Gotlin Culjak et al. 2007) and is also present in Albania and Slovakia, according to the DAISIE website.

Parameter fitting

The parameters for fitting the CLIMEX® model of *M. pruinosa* were inferred from its native geographic distribution and relative abundance in North America. Stress and growth indices were adjusted in an iterative manner until the model closely fitted the known distribution in North America. The parameters are summarized in Table 1 and their values are discussed below.

Growth indices

Temperature index

In temperate climatic zones, development and reproduction of *M. pruinosa* take place between the end of May and September. Relevant temperatures of cities at the northernmost and southernmost boundaries of *M. pruinosa's* geographical distribution were used to determine the minimum and maximum temperature limits (DV0, DV3). DV0 was set to 13°C, the average May temperature in Toronto (12.4°C) being used as the lower temperature threshold. With a DV0 of 12°C, locations in Manitoba, New Hampshire and New Brunswick were matched, but *M. pruinosa*

Table 1 CLIMEX® parameter values used to model *Metcalfa pruinosa's* distribution in North America and Austria

Indices	Code	Parameter description	Values
Temperature indices	DV0	Lower temperature limit	13°C
	DV1	Lower optimal temperature	22°C
	DV2	Upper optimal temperature	28°C
	DV3	Upper temperature limit	31°C
	PDD	Minimum degree-days above DV0 necessary to complete one generation	500
Moisture indices	SM0	Lower moisture index limit	0.25
	SM1	Lower optimal moisture index	0.5
	SM2	Upper optimal moisture index	1.0
	SM3	Upper moisture index limit	1.5
Cold stress	TTCS	Cold stress temperature threshold	−1°C
	THCS	Cold stress temperature rate	-0.0001 week^{-1}
Heat stress	TTHS	Heat stress temperature threshold	31°C
	THHS	Heat stress temperature rate	0.002 week^{-1}
Dry stress	SMDS	Dry stress threshold	0.25
	HDS	Dry stress rate	-0.005 week^{-1}
Wet stress	SMWS	Wet stress threshold	1.5
	HWS	Wet stress rate	0.002 week^{-1}
Diapause indices	DPD0	Diapause induction day length	9 h
	DPT0	Diapause induction temperature	0°C
	DPSW	Summer/winter diapause indicator	0

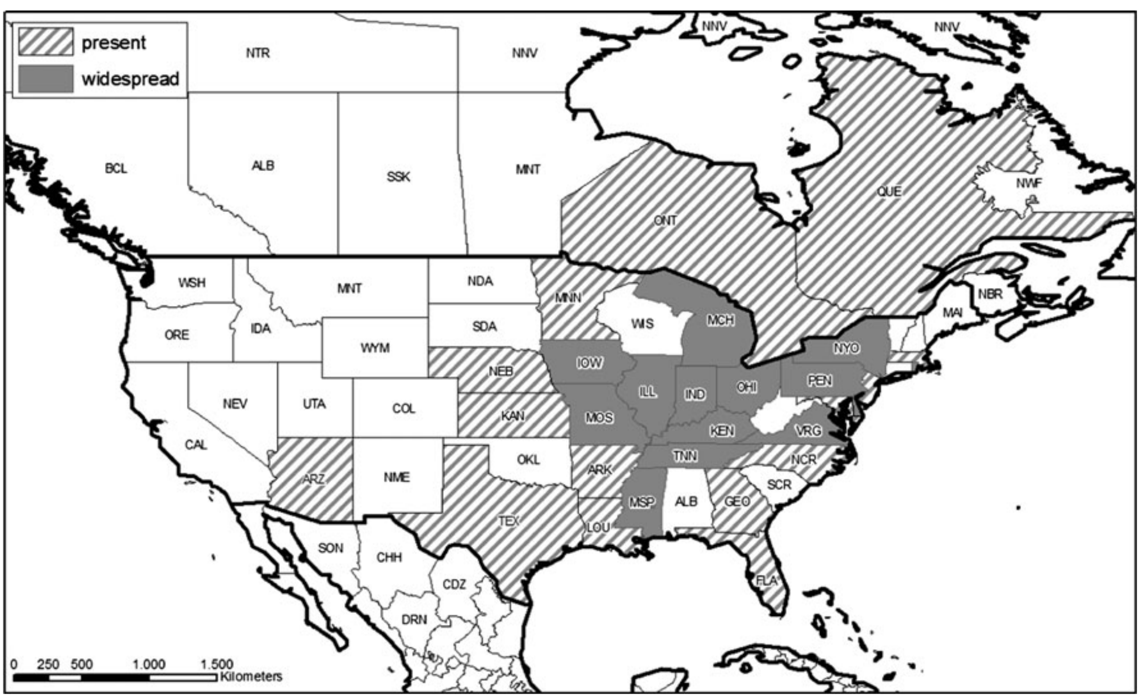

Fig. 1 Distribution of *Metcalfa pruinosa* in North America. *Shaded areas* indicate areas where this species has been found and not actual territory occupied

does not occur there. The average maximum May temperature in Weslaco, Texas (31.2°C) was used to define the upper temperature limit DV3 as 31°C. The lower optimal temperature DV1 was set to 22°C in line with the average June temperature in New York (22°C), because population growth is at a maximum rate at that time. The average maximum July temperature in Columbus (28.7°C) was used for the upper optimal temperature (DV2).

Thermal accumulation

The distribution of *M. pruinosa* is limited in cool environments by the length of the growing season, in which *M. pruinosa* can reproduce consistently. PDD is the minimum number of degree-days above DV0 necessary to complete one generation; 500 degree-days above 13°C were calculated to be necessary to complete one generation of *M. pruinosa* based on its phenology in Vienna (Kahrer et al. 2009). With more degree-days >13°C the distribution of *M. pruinosa* reduces in the north and excludes locations that are known to support permanent populations.

Diapause index

M. pruinosa populations have an obligate winter diapause and the winter diapause function was set (DPSW = 0) accordingly. As no scientific data for diapause parameters were found in literature, the respective temperature and day length were estimated. The Diapause Induction Day length (DPD0) was set to 9 h and the Diapause Induction Temperature (DPT0) to 0°C. Accordingly, diapause is induced as day length decreases below 9 h at temperatures below 0°C. These values enable diapause to be initiated in northern latitudes while also in subtropical areas in Florida.

Moisture index

The occurrence of *M. pruinosa* in North America was compared with the average annual precipitation in USA (source: http://nationalatlas.gov/printable.html). This species mainly occurs in regions where the annual average precipitation is between 610 and 1,625 mm. *M. pruinosa* has a limited distribution in dry regions, e.g. Arizona. The lower soil moisture threshold SM0 was set to 0.25 to match the records in Arizona.

M. pruinosa also occurs in areas with copious precipitation throughout the year, e.g. Louisiana and Mississippi. The upper threshold for soil moisture (SM3) was set to 1.5, a level that accounts for the presence of the planthopper in high rainfall areas. SM1 and SM2 were adjusted to maximize the growth potential in the area where this species is widespread.

Stress indices

Cold stress

The temperature at which cold stress begins (TTCS) was set to −1°C, so that places in Manitoba show a relative high cold stress value. With a higher TTCS, locations in Kentucky indicate cold stress for *M. pruinosa* which is unreliable. With lower temperatures the northernmost distribution is increased too far north and EI in New Brunswick and Maine indicate very good establishment for *M. pruinosa*, but where it does not occur.

Wet stress

The wet stress threshold was set equal to SM3 and the accumulation rate was adjusted to 0.002 week^{-1}, resulting in no wet stress in Louisiana and Mississippi.

Dry stress

The dry stress threshold was set to 0.25 and the rate of stress was adjusted to −0.005 week^{-1}, so that dry areas in Arizona are indicated as being marginal suitable.

Heat stress

The heat stress temperature threshold was set at 31°C to coincide with the temperature at which population growth ceases. It is presumed that heat stress does not accumulate rapidly and was adjusted to 0.002 week^{-1} to allow the planthopper to persist in south Texas.

Results

Probability of entry

In different European countries, *M. pruinosa* was first detected in nurseries and outdoor ornamental gardening centres, indicating that this pest is introduced into new areas via trade of plants for planting (Malumphy et al. 1994; Lauterer 2002; Kahrer and Moosbeckhofer 2003). Eggs are laid under bark where they are well protected during the winter. Survival of the pest in the egg stage during plant transport and storing is therefore very likely. In a survey about host plants of *M. pruinosa* used for oviposition in Vienna, numerous eggs were found on the following woody plant species: *Acer* ssp., *Ailanthus altissima*, *Buxus microphylla, Catalpa bignonioides*, *Clematis* ssp., *Deutzia* ssp., *Euonymus* ssp., *Fraxinus excelsior*, *Hibiscus* ssp., *Lonicera* ssp., *Mahonia aquifolium*, *Parthenocissus quinquefolia*, *Paulownia tomentosa*, *Prunus* ssp., *Robinia pseudoacacia*, *Rubus fruticosus*, *Sambucus nigra*, *Spirea* ssp., *Symphoricarpus albus*, *Viburnum burkwoodii* (Kahrer et al. 2009). Trade in these hosts is therefore considered an important pathway. *M. pruinosa* eggs were not found on herbs.

The highest risk of unintentional introduction of *M. pruinosa* arises from trade in deciduous trees and shrubs for planting from EU-member states, where *M. pruinosa* is

Table 2 Trade volume in euro of planting material into Austria from European countries which are the main trading partners (Statistic Austria 2008)

Country of origin	Trees, shrubs for planting		Fruit trees and shrubs		Vine with roots		Forestry plants	
	2004	2005	2004	2005	2004	2005	2004	2005
Italy	2,216,394	2,644,484	125,990	142,268	94,355	10,641	194,075	145,613
France	383,934	289,881	123,084	129,938	458,470	617,245	0	0
Slovenia	0	0	20,856	0	0	558,877	0	0
Germany	4,399,031	4,833,677	1,056,915	1,118,960	340,713	235,758	1,214,644	8,983,09
Netherlands	7,847,370	7,481,013	557,574	950,830	0	1,476	619,070	1,118,372

Countries where *M. pruinosa* occurs in italics

common. The main trading partners of Austria in this respect are Germany and the Netherlands (Statistic Austria 2008; Table 2). A. Sala (pers. comm. 2007) reported an isolated outbreak in a glasshouse in the Netherlands. Important trading partners, with high prevalence of the pest species are Italy, France and Slovenia. Less important ones are Greece, Spain, Hungary and Bulgaria because *M. pruinosa* occurs only in small areas and import rates are relatively low. However, there is some uncertainty regarding how widespread *M. pruinosa* is in these countries.

Italy is the third most important trading partner of planting material (Table 2). The pest is widespread throughout the country although population levels were reduced by biological control with *Neodryinus typhlocybae* (Ashmead 1893) (Hymenoptera: Dryinidae) (Tommasini et al. 1998). Association of *M. pruinosa* with this pathway is assumed to be particularly high.

In France, *M. pruinosa* is present in the South (Malausa et al. 2003) with the following regions infested: Provence-Alpes-Côte d'Azur, Rhônes-Alpes, Languedoc-Roussillon, Midi Pyrénées and Aquitaine. In Midi Pyrénées, *M. pruinosa* was put on a list of organisms, against which chemical control is obligatory (SRPV Midi-Pyrénées 2002). These official control measures reduce the likelihood of association of the pest with the pathway in Midi Pyrénées (Source: Recueil des Actes Administratifs de la Préfecture du Lot 2006). A moderately high probability of entry remains for trade of deciduous plants from other infested regions in France, since no information was found that such official control measures are applied. Since 1996, *M. pruinosa* has been regulated biologically by *N. typhlocybae*, which has been released in about 96 locations in France (infested nurseries, gardens) but spread of the pest was reported to be faster than that of its natural enemy. Some important vine growing regions in France are already infested, and France is one of Austrian's most important trading partners of vine with roots beside Hungary, Germany and Slovenia (Statistic Austria 2008).

Entry of *M. pruinosa* from Slovenia into Austria is considered unlikely, since trade volume of deciduous plants for planting is of only minor importance (Table 2).

Plants for planting are traded during the non-vegetative season. At this time, only eggs of *M. pruinosa* are present. Adults and nymphs are conspicuous and are likely to be detected, whereas the eggs are very likely to remain undetected by visual inspection. Wax filaments may indicate the presence of the pest, because they remain on the plant even when the pest has moved to another location, but are not a distinct evidence for *M. pruinosa*. Furthermore, *M. pruinosa* feeds on many plant species for which a plant passport is not necessary. Infested ornamental plants are likely to be widely distributed throughout the PRA area and the planthopper can easily transfer to other host plants through its ability to jump and fly.

Another pathway to consider is entry by vehicle traffic. *M. pruinosa* was found along roads, buslines, motorways and parking sites in different European countries (Bozic 2004). In Switzerland, *M. pruinosa* was found on a motorway for the first time in Ticino. It is supposed that this planthopper was introduced into Ticino by means of vehicle traffic on the principal route of commerce with Italy (Jermini et al. 1995). Association of *M. pruinosa* with vehicles is facilitated through the fact that this species lives on many wild plants which also grow along roads and parking sites. Probably only few individuals are taken along but it is assumed that for establishment of a new population few individuals could be enough. Austria is a transit country due to its geographical situation in the centre of Europe. Intra-EU road freight from Italy, France and Slovenia to Austria amounted to 4655, 931 and 699 thousand tonnes in 2004, respectively (Eurostat 2007). Road transport is short enough for survival of the adult planthopper, which lives for about 10 days (Wene 1950).

Passive spread by tourist travel from Italy and Croatia into Austria during the summer holiday season may also be considered as a minor pathway. According to Statistic Austria (2008), Italy is the most important destination

(20%) followed by Croatia (11%), Germany (9%), Spain (7%) and Greece (6%). In 2006, 57.5% (number of cars: 5,025,300) of the main holiday trips were made by car (Verkehrsclub Österreich 2007). In general, adults of *M. pruinosa* occur from the end of July until the end of October and are therefore present during the summer holiday season. *M. pruinosa* occurs in many parts of Croatia, including coastal areas, such as Istria (Seljak 1993).

Probability of establishment and spread

Modelled distribution of M. pruinosa in North America

The simulated distribution of *M. pruinosa* corresponds closely with the known range in North America (Figs. 1, 2). Thus, the strong agreement suggests that the model is reasonable. The whole eastern part of the USA is climatically suitable for *M. pruinosa*. Its northernmost occurrence can be explained by a combination of lack of heat accumulation for the completion of a generation and cold stress. Mainly dry stress impede *M. pruinosa* to expand largely into the western states of the USA. Parts of North and South Dakota as well as Manitoba, Wyoming and California are indicated as only marginal suitable for *M. pruinosa*. It is assumed that the planthopper could persist only in very scattered populations with large annual fluctuations in numbers under these climatic conditions.

Modelled potential distribution of M. pruinosa in Austria

Permanent establishment of *M. pruinosa* has already occurred in a few distinct sites in Austria but establishment is likely in more sites. The projections of climatic suitability under current climate conditions with the CLIMEX® model reveal that conditions for establishment of *M. pruinosa* are most favourable in the east of Austria where fruit- and vine-growing areas are also located, and become increasingly unfavourable towards the west, due to cooler temperatures. *M. pruinosa* has the best chance of establishment in the southern part of Burgenland as well as south-eastern Styria with its Illyrian climate, followed by, Lower Austria (Industrie-, Most- and Weinviertel), and the Danube river valley in Upper Austria. These regions are considered as the endangered area (Fig. 3). The highest ecoclimatic index is shown by Graz (EI = 19) in Styria, where a naturalized population exists. The north-eastern part of Lower Austria (Weinviertel and Marchfeld) as well as the northern part of Burgenland and Vienna (EI = 17) are comparably less favourable due to a relatively dry climate (average total precipitation ~ 600 mm). In Carinthia, only the Klagenfurt Basin in the south-east is favourable for establishment (Klagenfurt: EI = 11). The subalpine and alpine regions are indicated as unsuitable for establishment due to cold stress and insufficient thermal accumulation at these altitudes.

From a survey in Vienna on *M. pruinosa's* distribution, it was concluded that natural spread is proceeding slowly and only locally (up to 0.5 km/year) (Kahrer et al. 2009). However, data on wind dispersal is lacking. In Vienna, *M. pruinosa* occurs in high numbers in a public park, which is visited by runners and residents from the local vicinity, who may spread the pest unintentionally. Spread by human activities is likely.

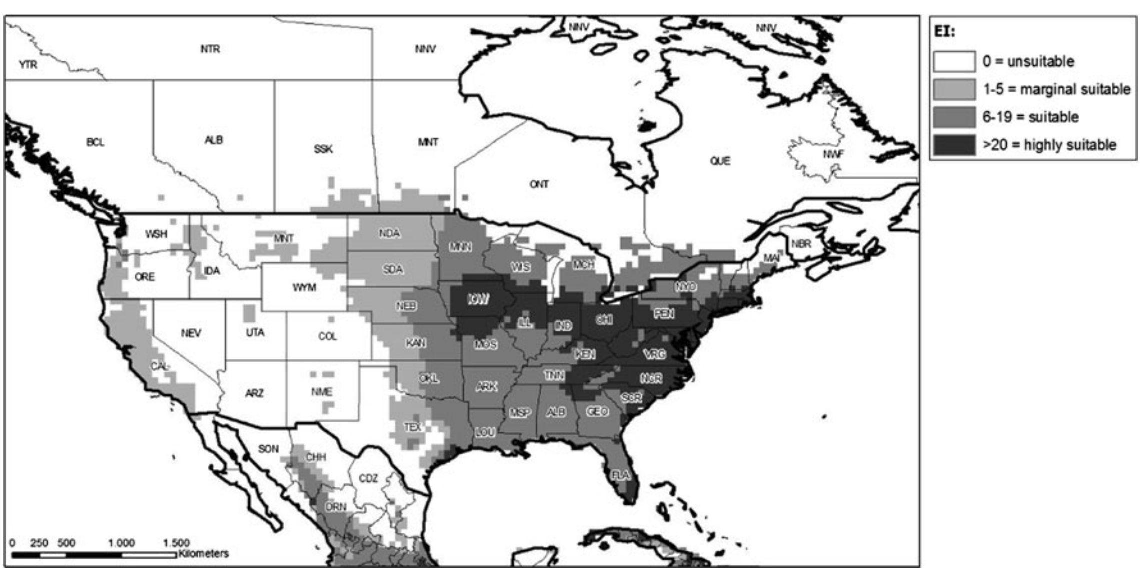

Fig. 2 Geographical distribution of *Metcalfa pruinosa* in North America, as estimated by the CLIMEX® ecoclimatic index, EI

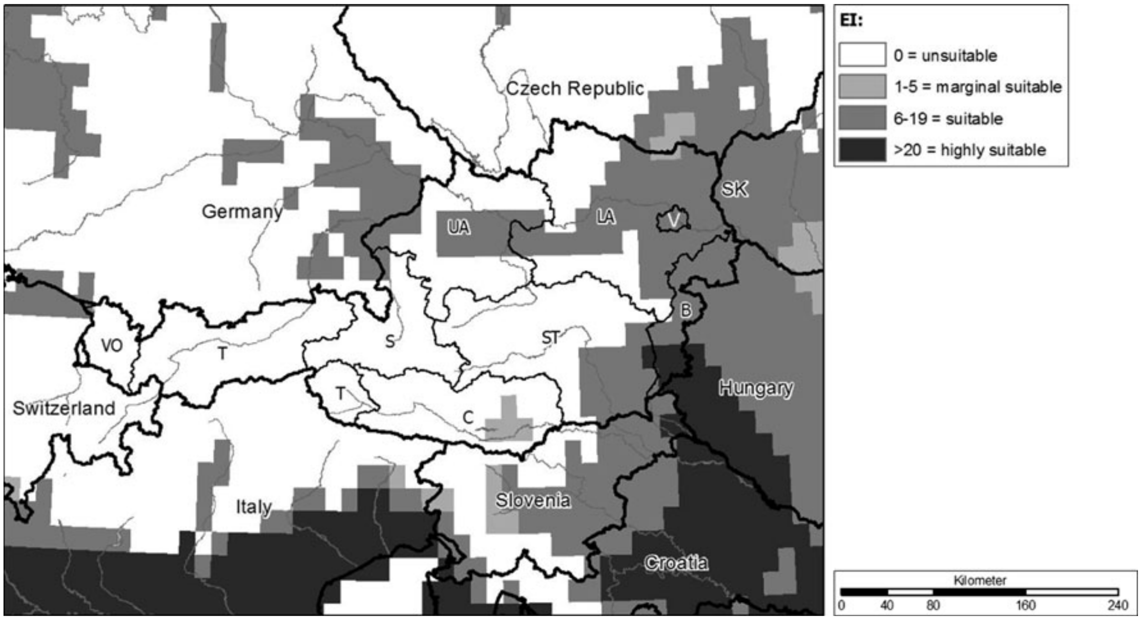

Fig. 3 Potential geographic distribution of *Metcalfa pruinosa* in Austria and neighbouring countries as estimated by the CLIMEX® ecoclimatic indices (EI). *V* Vienna, *LA* Lower Austria, *B* Burgenland, *UA* Upper Austria, *ST* Styria, *C* Carinthia, *S* Salzburg, *T* Tyrol and *VO* Vorarlberg

Probability of economic impact

In Italy, France, Slovenia, Croatia and Bosnia Herzegovina, *M. pruinosa* caused severe damage to orchards and vineyards through contamination of fruits with honeydew on which sooty moulds developed (Karsavuran and Güçlü 2004; Souliotis et al. 2008; I. Žežlina pers. comm. 2007). Reduced fruit quality caused by *M. pruinosa's* honeydew secretions was recorded on the following crops: *Actinidia deliciosa*, *Cucumis melo* ssp., *Diospyros kaki*, *Ficus carica*, *Juglans regia*, *Malus* sp. (Greatti and Girolami 1994), *Medicago sativa*, *Olea europaea*, *Prunus persica*, *Prunus armeniaca*, *Prunus domestica*, *Prunus avium*, *Pyrus* sp., *Vitis vinifera*, *Zea mays* (Duso 1984; Stefanelli et al. 1994; Ciampolini et al. 1995). Current pest management strategies in orchards and vineyards could not prevent establishment and damage of *M. pruinosa* (Stefanelli et al. 1994). In Italy, France, Slovenia, Switzerland, Croatia, Greece, the Netherlands and Spain the introduced parasitic wasp *N. typhlocybae* from North America is used to control *M. pruinosa* biologically (Tommasini et al. 1998; Ciglar et al. 1998; Jermini et al. 2000; Žežlina et al. 2001; Malausa 1999; A. Sala, pers. comm. 2007).

In Austria, *M. pruinosa* is mainly present in public green areas and private gardens but not in vineyards or orchards. In nurseries, the nymphs and their white wax secretions are of minor importance. According to the CLIMEX® simulation, the regions of central and southern Burgenland, south-eastern Styria and Lower Austria, provide a suitable climate for the development of the pest. The main fruit- and vine-growing areas are located in these regions. The greatest proportion of the viticulture area in Austria is in Lower Austria and Burgenland (91.8%) (BMFLUW 2005). The second largest viticulture region lies in Styria with a portion of 6.7%.

In 2007, Styria had the biggest proportion (65%) of the fruit-growing area in Austria (12,400 ha), followed by Lower Austria (17%), Burgenland (7%) and Upper Austria (6%). Pome fruits are most important, with apples (*Malus* ssp.) produced on 7,200 ha, berries on 1,900 ha and stone fruits on 1,400 ha. From 2002 to 2007, the production size of apricot (*P. armeniaca*), pears (*Pyrus communis*) and cherry (*Prunus* ssp.) increased (Grüner Bericht 2008).

Damage by *M. pruinosa* is to be expected in crops in which no or few insecticides are applied. In Austria, organic production is important and steadily increasing since 2002. Fruits are produced organically on 1,100 ha, mostly pome fruit (51%), but also berries (18%), elder (*Sambucus nigra*) (14%) and stone fruit (9%) (Grüner Bericht 2008). It is likely that *M. pruinosa* will cause major damage to crop quality in organic production and its control could be more difficult due to the reduced control opportunities. For organic production, the only realistic control method would be the release of non-native parasitoid *N. typhocybae*, which is not yet permitted in Austria. Based on the significant reduction of the pest and crop damage through the release of *N. typhlocybae* in Italy, France and Slovenia, it is probable that also in Austria the economic risk of *M. pruinosa* would be acceptable when biologically controlled (Gervasini 2001; Girolami and Mazzon 2001) .

The objective of Austria's agricultural policy is an ecological orientation promoted with the help of the Agri-environmental program ÖPUL 2007 (BMFLUW 2008). Integrated production with limited use of plant protection products is common in Austria. Approved insecticides against sucking insects and leafhoppers in viticulture and orchards in Austria in 2008 were Confidor 70 WG (Imidacloprid; Reg. No. 2602), Samba K (Fenpyroximat; Reg. No. 2762), Reldan 2E (Chlorpyrifos-methyl; Reg. No. 2225) and Steward (Indoxacarb; Reg. No. 2737) (AGES, www.psm.ages.at). In general, *M. pruinosa* is difficult to control chemically because it has a protracted hatching period and may infest cultivated land from nearby over-wintering sites in natural environment. In the long term, production cost would increase due to additional insecticide application. An important disadvantage of spraying is that this method is only certified for agricultural use in Austria, but *M. pruinosa* was mainly found in natural environments. However, pesticide application would not completely control the pest in all infestation areas and no long-term control would be achieved.

Discussion

The EPPO decision support scheme for quarantine pests proved to be a useful instrument to assess the probability of introduction, spread and economic consequences of a potential new pest species. With this detailed scheme it is possible not only to evaluate the total phytosanitary risk of a species, but also to better understand the conditions and relations that may lead to that risk.

From the pathway analysis, clear evidence exists that entry of *M. pruinosa* in the egg stage is likely through trade of deciduous plants for planting from Italy and France, based on the documented incidences. Accordingly, nurseries and ornamental gardening centres are the main entry points for *M. pruinosa* into Austria. The likelihood of association, survivability and transfer to host plants of *M. pruinosa* by traffic (road freight and travellers) from Italy and Croatia into Austria is more difficult to ascertain because this pathway is not well documented and the uncertainty factor is therefore higher. Interception data of *M. pruinosa* in consignments would be necessary to indicate the concentration of the pest on the pathway and its ability to survive in transit.

From the CLIMEX® analysis, it was possible to clearly identify those regions in Austria which are climatically most suitable for this species and to define the endangered area, although the resolution of the CLIMEX® does not allow statements on a local level. Nevertheless, with CLIMEX® it is possible to indicate where a foreign species would be able to become established if it was introduced into a new area, and this is an essential part of risk assessment.

Organic produced orchards and vineyards in Burgenland, Lower Austria and Styria are economically most at risk of being damaged by *M. pruinosa*, particularly those close to infested sites in Vienna and Graz, since it is very likely that the planthopper will continue to spread. For sustainable management of the pest innoculative release of *N. typhlocybae* is recommended, but requires compulsory approval in a similar way to conventional plant protection agents.

During the risk analysis it became apparent that some questions were difficult to answer because the necessary information does not exist. According to Alma et al. (2005), *M. pruinosa* is considered an invasive species but the ecological effects of its introduction have not yet been investigated. In the field, direct negative effect on *Urtica dioica* was observed, which obviously suffered from the sucking activity of *M. pruinosa* nymphs and wilt (G. Strauss, unpublished data 2006). *U. dioica* is an important host plant for some endangered butterfly species (*Inachis io* L., *Aglais urticae* L., *Araschnia levana* L. and *Vanessa atalanta* L.), which could be indirectly affected through damage to their host plant. Individuals of *M. pruinosa* were found to be infested with different phytoplasma groups (Danielli et al. 1996) but in transmission experiments *M. pruinosa* failed to transmit Grapevine flavescence dorée phytoplasma (FDP) and clover phyllody (Clair et al. 2001; Bressan et al. 2006). These results support the assumption that transmission of plant pathogens by *M. pruinosa* seems unlikely but this knowledge is based on only a few transmission tests. Further transmission experiments are necessary, in particular regarding the large spectrum of host plants.

To prevent further introduction, spread and economic damage of *M. pruinosa* in Austria the following measures should be considered: (1) trade of woody plants for planting from pest-free place of production, (2) periodic inspections of woody plants for *M. pruinosa* nymphs in June, (3) specific inspection for wax filaments, (4) biological control of *M. pruinosa* with *N. typhlocybae* at infestation sites, (5) pesticide use against the young immature stages of *M. pruinosa*, (6) enhance public awareness of this pest and (7) periodic inspections of parking sites along main transport routes for *M. pruinosa*.

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