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Temporal dynamics of *Scaphoideus titanus* populations: from annual occurrence patterns to changing climate suitability assessments

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Abstract: A previously published model based on a time-varying distributed delay with attrition is used to simulate, at three different temporal scales (one, five and fifty-two years), the dynamics of the invasive grape leafhopper *Scaphoideus titanus* Ball in vineyards located in Southern and Western Switzerland. The model was parameterized with laboratory and field data. Built on population theory principles and driven by daily temperature maxima and minima and grapevine plant phenology it satisfactorily represents annual and multiannual occupancy patterns and hence, is concluded to have satisfactory predictive and explanatory capabilities. The simulations representing canopy occupancy by non-diapausing eggs, nymphs and emerging adults are particularly useful for tactical purposes including the timing of monitoring operations and insecticide applications. The simulations representing canopy occupancies by diapausing eggs, non-diapausing eggs, nymphs and adults are useful for strategic purposes. Growers and extensionists should be aware that rather stable occupancies are maintained once an area suitable for development is invaded and no management operations are undertaken. The simulations by the validated model representing long term dynamics could be useful for strategic purposes, policy design and research work. Namely, the model produces an index that represents the climate suitability of a region for colonization by *S. titanus*. A temporal coincidence was observed between a climate that lifted the temperatures by about 1 °C shift at the end of the 1980s and an abrupt change of the index at the Locarno-Magadino and Geneva sites. If verified at other locations, the climate suitability may have little changed after the introduction and hence, the colonized areas remained relatively constant. At the end of the 1980s, however, new areas were successfully colonized, presumably as a result of now favorable climate conditions and a sufficient dispersal ability of *S. titanus*. Extensionists and policy makers could take note of a future invasion and prepare growers for dealing with a new pest.

Key words: invasive potential, simulation, climate suitability index, temporal scales, institutions, decision support

Introduction

The grape leafhopper *Scaphoideus titanus* Ball is a major pest in many European vine growing regions where it vectors the Flavescence dorée (FD) phytoplasma which is a quarantine pathogen. After the accidental introduction in the 1950s, *S. titanus* invaded vineyards in France, Northern Italy and neighbouring Southern Switzerland, and Slovenia. Until the end of the 1980s, no further spread was reported and these regions were thought to delimit the geographic distribution. Thereafter, however, *S. titanus* extended rapidly the area of distribution towards Northern and Eastern Europe. Actually, it is present throughout

Western and Southeastern Europe from the Atlantic Ocean to the Black Sea (Chuche & Thiéry, 2009; Avremov *et al*., 2011; Chireceanu *et al*., 2011).

Rigamonti *et al*. (2011, 2013) and Jermini *et al*. (2013) contributed to the acquisition of knowledge indispensable for the understanding of *S. titanus* population development and for control system design and implementation. Nevertheless, the available information is still inadequate for developing and implementing cost efficient control measures at tactical, strategic and policy levels. These levels are the result of the structuring of the institutions involved in pest management (Conway, 1984). In all invaded areas, growers undertake mandatory chemical control measures in accordance with region-specific needs and regulations. In areas not colonized but suitable for *S. titanus* population development, adequate knowledge on the climatic suitability would allow policy makers and administrators to prepare growers and extensionists for possible future control activities. In already invaded areas, adequate knowledge on multi-annual infestation patterns is helpful for designing control strategy of interest to extensionists and growers (Rigamonti *et al.*, 2013). They may also benefit from tactical advice on control activities encompassing monitoring and timing of chemical control measures (Rigamonti *et al*., 2011).

The purpose of this paper is to briefly refer to two simulation model versions by Rigamonti *et al*. (2011, in press) representing within-generation and multiple-generation vine plant infestation patterns and to add a third version producing long term time series of vine plant occupancy patterns. The evaluation of the third version is expected to contribute to an explanation of the aforementioned invasion patterns in Europe under climate change influence and assist in assessing the risk that a still unoccupied area is invaded in the near future.

Material and methods

In three versions, a time-varying distributed delay with attrition is used to simulate the dynamics of *S. titanus* life stages (diapausing eggs, non-diapausing eggs, nymphs, adult females) in Southern and Western Switzerland at three different temporal scales (one, five and fifty-two years). The model is based on principles of population dynamics (Rigamonti *et al*., 2011, *in press*). Version one deals with non-diapausing egg and nymphal development only. Version two and three simulate diapause and non-diapause development of eggs, nymphs, and the senescence and fecundity rates of female adults. The mortality rates of all life stages considered and the diapause process are temperature dependent. In versions two and three, mortality of non-diapausing life stages is increased by plant dormancy and low temperatures. In versions two and three, the developmental rate of the plant and the occurrence of the phenological stage BBCH11 for the Chardonnay variety are obtained from the functions provided by Wermelinger *et al*. (1991, 1992) and Mariani *et al*. (2007, 2013), respectively. The plant is suitable for *S. titanus* development between BBCH11 and leaf fall, obtained from observations made in Southern Switzerland. For the details on the structure, parametrization and validation of the model versions, the reader is referred to Rigamonti *et al*. (2011, in press).

Version one simulates within generation processes and supports decisions by growers and extensionists (Rigamonti *et al*., 2011). Version two simulates multiannual infestation patterns and supports strategic decisions (Rigamonti *et al*., 2013, in press). Here, we present the results of the simulations by version one and two at the Contone and Lutry sites in Southern and Western Switzerland, not subjected to insecticide treatments. The consideration of population dynamics principles and the validations with extensive field data sets resulted in a favourable qualification of the explicative and descriptive capabilities of version one and two (Rigamonti *et al.*, 2011, *in press*). The simulated infestation patterns produced by version one and version two are depicted in Figures 1 and 2.

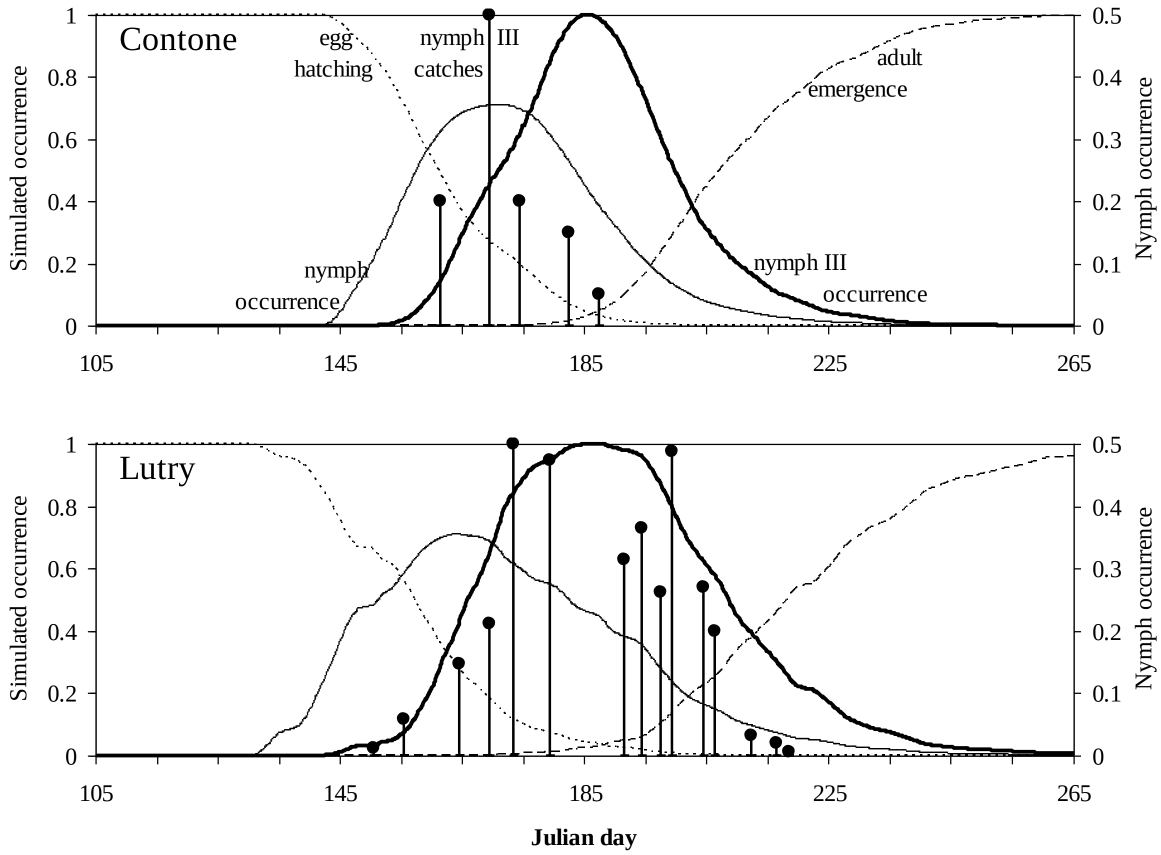

Figure 1. The dynamics of the predicted age structure of *S. titanus* populations and the observed catches of third-instar nymphs relative to the respective maximum number at the Contone and Lutry vineyards. The simulated occurrences of third-instar nymphs and adults are related to the respective maximum occurrence.

The positive qualification of model version one and two motivated us to change model version two and use it as version three for the simulation of long term time series of infestations covering a time period beginning during the invasion (1959) and ending in 2012. To represent the climate suitability we calculated an index based on the occurrence of eggs at BBCH11 in the Chardonnay variety in the current year divided by the occurrence in the previous year. To allow the model initialized with a restricted data set to adjust to other sites and years, the first two years are disregarded so that 52 index values are obtained from a 54 years data set. Temperature is assumed to be the most important abiotic factor and used to represent climate conditions. If the index is below one, the temperature regime is unsuitable for *S. titanus* development and its density decreases. An index greater than one, indicates favourable temperatures responsible for increasing *S. titanus* development. At the Locarno and Geneva sites in Southern and Western Switzerland, version three simulates the long term infestation patterns depicted in Figure 3 thought to be of interest in assessments of climate change impacts.

For the periods under study, Meteoswiss kindly provided site-specific daily maxima and minima temperatures from the Locarno-Magadino, Pully and Geneva meteorological stations. During the 54 years measuring period at the Locarno-Magadino and Geneva sites changes occurred in temperatures measurements. MeteoSwiss kindly provided a homogenised data set in that these changes are taken into account (Begert *et al*., 1999; 2003; 2005).

Results and discussion

Figure 1 represents the observed and predicted annual occurrences of nymphs in the vine plant canopy of the untreated Contone and Lutry vineyards. As noted by Rigamonti *et al*. (2011), the satisfactory explicative and predictive qualities allow the use of model version one for organizing monitoring activities and timing pesticide treatments. Of interest is the appearance of the third nymphal stage as a trigger for insecticide applications. The use of this version has been rationalized within a Web Based Adaptive Management System (WAMS) (Prevostini *et al*., 2013).

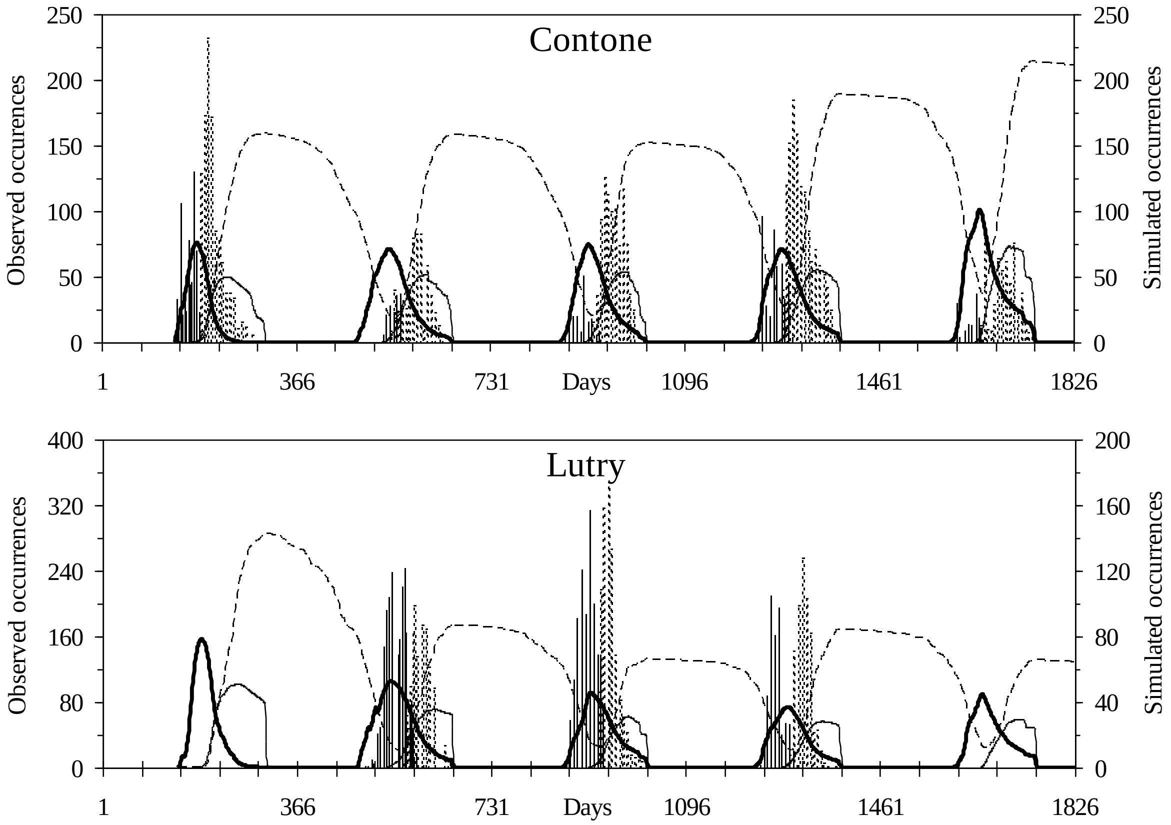

Figure 2. The simulated egg occurrence/2 (broken line), simulated larvae occurrence (thick solid line), simulated adult occurrence (thin solid line), observed nymphs (solid column), observed adult (broken column) at the Contone and Lutry vineyards in the 2006-2010 period.

Figure 2 represents the observed and predicted multiannual occurrence patterns in the same vineyards. For Contone and Lutry as well as for additional untreated vineyards not reported here the occupancy appeared to be stable over the five years periods. This information is important for extensionists and growers alike, because over short time periods, they obtain similar reliabilities for population estimates in fixed sample size monitoring programs in untreated vineyards and may have little concerns for widely fluctuating population densities in population control. Rigamonti *et al*. (2013) concluded that satisfactory explicative and predictive qualities of model version allowed the integration into the Web Based Adaptive Management System (WAMS) (Prevostini *et al*., 2013).

Figure 3 represents the long term patterns of the climate suitability index driven by the homogenized temperature recordings at the Locarno Magadino and Geneva meteorological stations. A visual examination of Figure 3 indicates a relatively stable index prior to 1988 and an increase thereafter. To elucidate the difference between the two patterns, two circles surround the respective values of the index (Figure 3). It is unclear how the temperatures recorded at the meteorological stations reflect the conditions in the nearby grapevine growing areas; at least in Geneva, the temperatures experienced by *S. titanus* populations are likely to be higher than the ones driving population development in model version three. Hence, the interpretation of Figure 3 is limited to some tentative remarks whose validity should be evaluated in climatic studies. In general, the climate suitability is higher at Locarno-Magadino than at Geneva. At Locarno Magadino, the conditions appear to be unsuitable before 1988 but allowed a slight population increase in many but not all years thereafter. To some extent, this pattern may reflect the rather stable infestation patterns produced by model version two for the last five years (Figure 2). At Geneva, however, the temperature regime was unfavorable during the entire period. If we accept that the temperatures experienced by *S. titanus* are higher than the ones use to generate Figure 3, we may obtain favorable conditions in some recent years. Possibly, this contributes to an explanation of the colonization of the Lac Léman area that occurred only recently.

Meteorologists have observed an ”abrupt climate change” in Europe at the end of the 1980s that caused an increase of about 1 °C in the temperatures (Mariani *et al*., 2012). Interestingly the quantitative effects on crop plants were different in the different parts of Europe, according to the crop species and the local climate. On the basis of this climate change, Mariani *et al*. (2012) computed a general increase in thermal resources in the European continent for C3 and C4 plants adapted to high or moderate temperatures and obtained a decline of thermal resources for cold adapted C3 crops, in the Mediterranean area. In our opinion, a similar response can also be expected for crop pests. The temporal coincidence between this climate shift and the change of the index in Figure 3 suggests that the climate change is responsible for the improved suitability of the Locarno and Geneva sites. Extensionists who observed the appearance of *S. titanus* in the lake Geneva region in 2006 (Schaerer *et al*., 2007) should be aware that the conditions for *S. titanus* are likely to further improve to exacerbate the pest problem. They should also inform policy makers and colleagues in neighboring regions that their areas may become suitable and colonized in the foreseeable future, if the dispersion ability of *S. titanus* permits.

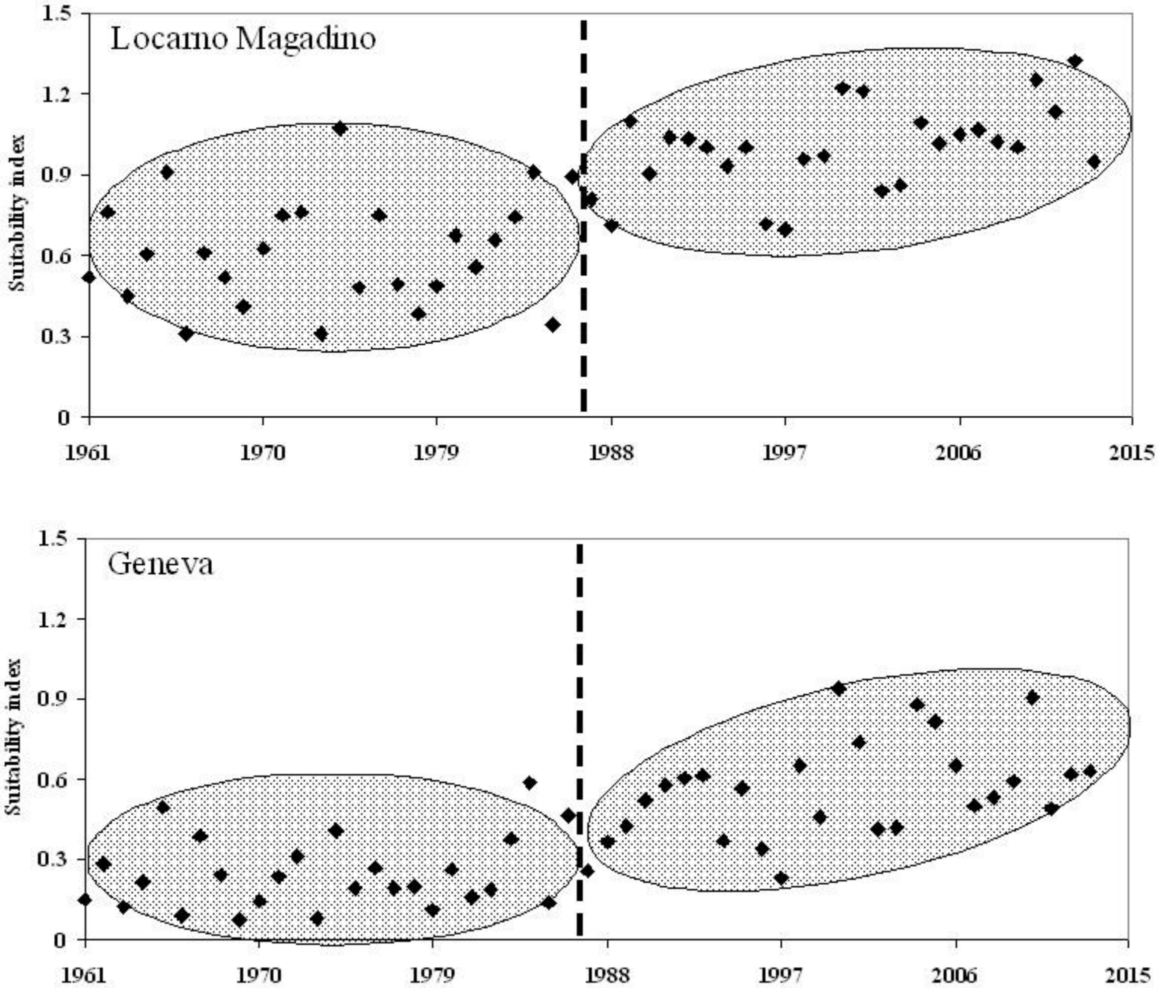

Figure 3. The values of the climate suitability index at Locarno Magadino and Geneva for the 1961-2012 time series. The vertical broken line marks the climate change that occurred in 1987.

Figure 3 may also point to the possibility of using model version three to explain the aforementioned differences between the spreads of *S. titanus* prior and after the end of the 1980ies in Europe. Assuming that the result can be extended to other regions, we hypothesize that the climate suitability has little changed after the introduction and hence, the colonized areas remained relatively constant. At the end of the 1980s, however, new areas were successfully colonized, presumably also as a result of now favorable climate conditions and a sufficient dispersal ability of *S. titanus*. However, to ascertain this spatio-temporal dynamics and to develop a tool supporting decisions of extensionists and policy makers, additional work should be undertaken along the following lines. First, the study focusing on Locarno and Geneva should be extended as to cover the grapevine growing regions of Europe. Second, the visual examination of infestation patterns should be replaced by a statistical analysis. The result of these studies, combined with knowledge on dispersal abilities of *S. titanus*, are considered indispensable for assessing both the invasive potential of *S. titanus* and the risk for a future colonization of new areas.

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References

Avremov, Z., Ivanova, I. & Laginova, M. 2011: Screening for phytoplasma presence in leafhoppers and planthoppers collected in Bulgarian vineyards. Bull. Insectology 64 (Supplement): S115-S116.

Begert, M., Giroud, M., Kegel, R., Seiz, G., Koehli, V., Bochnicek, O., Fukasz, M., Nieplova, E. & Sramo, L. 1999: Operational homogenization of long term climate data series a SMI and SHMI. In: Proceedings of the 2nd Seminar of Homogenization of Surface Climatological Data, Budapest, 9-13 November 1998. WCDMP-No. 41, WMO-TD No. 962. HMS-WMO.

Begert, M., Seiz, G., Schlegel, T., Musa, M., Baudraz, G. & Moesch, M. 2003: Homogenisierung vom Klimareihen der Schweiz und Bestimmung der Normwerte 1961-1990. Schlussbericht des Projekts NORM90. Veröffentlichung der MeteoSchweiz, vol. 67. Meteoschweiz, Zurich.

Begert, M., Schlegel, T. & Kirchhofer, W. 2005: Homogeneous Temperature and Precipitation Series of Switzerland from 1864 to 2000. Int. J. Climatol. 25: 65-80.

Chireceanu, C., Ploaie, P. G., Gutue, M., Nicolae, I., Stan, C. & Comsa, M. 2011: Detection of the auchenorrhyncha fauna associated with grapevine displaying yellows symptoms in Romania. Acta phytopathol. Hun. 46(2): 253-260.

Chuche, J. & Thiéry D. 2009: Cold winter temperatures condition the egg-hatching dynamics of a grape disease vector. Naturwissenschaften 96: 827-834.

Conway, G. R. 1984: Introduction. In: Pest and Pathogen Control: Strategic, Tactical, and Policy Models (ed. Conway, G. R.): 1-11. Wiley, Chichester, UK.

Jermini, M., Trivellone, V., Cara, C., Rigamonti, I. E. & Baumgärtner, J. 2013: Marrying research and management activities: adaptive management of Grape leafhopper *Scaphoideus titanus*. IOBC-WPRS Bull. 85: 49-56.

Mariani, L., Failla, O., Dal Monte, G. & Facchinetti, D. 2007: IPHEN: a model for real time production of grapevine phenological maps. Congress on Climate and Viticulture, Zaragoza, 10-14 April, 2007: 272-278.

Mariani, L., Parisi, S. G., Cola, G. & Failla, O. 2012: Climate change in Europe and effects on thermal resources for crops. Int. J. Biometeorol. 56: 1126-1134.

Mariani, L., Alilla, R., Cola, G., Dal Monte, G., Epifani, C., Puppi, G. & Failla, O. 2013: IPHEN – a real-time network for phenological monitoring and modelling in Italy. Int. J. Biometeorol. 57: 881-893.

Prevostini, M., Taddeo, A. V., Balac, K., Rigamonti, I. E., Baumgärtner, J. & Jermini, M. 2013: WAMS – an adaptive system for knowledge acquisition and decision support: the case of *Scaphoideus titanus.* IOBC-WPRS Bull. 85: 57-64.

Rigamonti, I. E., Jermini, M., Fuog, D. & Baumgärtner, J. 2011: Towards improved understanding of the dynamics of vineyard infesting *Scaphoideus titanus* leafhopper populations for better timing of management activities. Pest Manag. Sci. 67: 1222-1229.

Rigamonti, I. E., Trivellone, V., Jermini, M. & Baumgärtner, J. 2013: Multiannual infestation patterns of grapevine plant canopy inhabiting *Scaphoideus titanus* Ball leafhoppers. IOBC-WPRS Bull. 85: 43-48.

Rigamonti, I. E., Trivellone, V., Jermini, M., Fuog, D. & Baumgärtner, J. in press: Multiannual infestation patterns of grapevine plant inhabiting *Scaphoideus titanus* (Hemiptera: Cicadellidae) leafhoppers. Can. Entomol.

Schaerer, S., Johnston, H., Gugerli, P., Linder, C., Shaub, L. & Colombi, L. 2007: “Flavescence dorée“ in Switzerland: spread of the disease in canton of Ticino and of its insect vector, now also in cantons Vaud and Geneva. Bull. Insectology 60: 375-376.

Wermelinger, B., Baumgärtner, J. & Gutierrez, A. P. 1991: A demographic model of assimilation and allocation of carbon and nitrogen in grapevines. Ecol. Model. 53: 1-26.

Wermelinger, B., Candolfi, M. P. & Baumgärtner, J. 1992: A model of the European red mite (Acari, Tetranychidae) population dynamics and its linkage to grapevine growth and development. J. Appl. Entomol. 114: 155-166.