Temperature–dependent development and reproduction of the whitefly Trialeurodes vaporariorum
Westwood (Hemiptera: Aleyrodidae)

Abstract
With the Insect Life Cycle Modeling (ILCYM) software, the obtained data on the temperature-dependent development of *T. vaporariorum* was used to develop a process-based temperature phenology model. After, the model was used to estimate two risk indices: the establishment risk index (ERI) that identifies areas in which the pest may survive and become permanently established and the generation index (GI), which estimates the mean number of generations the pest may produce within a given year. Further, a mapping and quantification of these indices changes between the climate scenarios of the years 2000 and 2050 was conducted using downscaled data of the scenario A1B from the International Center for Tropical Agriculture (CIAT) database. The study concludes that *T. vaporariorum*’s potential damage will progressively increase in highlands and temperate regions and may decrease in warmer cropping regions of the tropics and subtropics.

Introduction
The whitefly *T. vaporariorum* is an insect with five immature life stages that includes egg, and four stages of nymphs (nymph I, II, III, and IV) and an adult stage (male and female). This species is a major pest worldwide that causes direct damage on potato yield and quality. *T. vaporariorum* also affects indirectly potato growth as it transmits *Potato yellow vein virus* (*PYVV*), which can reduce yield up to 80% (Fig. 1). The objective of the present study was to predict the potential risk of distribution and abundance of this pest in potato cropping regions worldwide under different climate change scenarios. For this purpose a phenology model was developed and coupled to Geographic Information System (GIS) for risk mapping.

Results and Discussion
Regions where the ERI is >0.95 indicates temperature conditions where a certain proportion of the *T. vaporariorum* population is expected to survive throughout the year, representing the regions where the likelihood of establishment is highest. In zones where the ERI deviates from the maximum number of 1 the likelihood of long-term establishment is reduced, but *T. vaporariorum* is also observed in regions with an ERI>0.60 as in northern Africa or Southern Europe. Actually, *T. vaporariorum* is already distributed or presents a severe risk (ERI>0.6) for tropical and subtropical potato production areas of Africa, Oceania, South America, and Asia (Evans et al. 1998, Evans et al. 1999, Evans et al. 2007) (Fig. 6). In contrast, *T. vaporariorum* is least established in North America and Europe. Under the year 2050 climate Scenario, the boundaries for *T. vaporariorum* are indicated to shift further north in the northern hemisphere of North America, Europe and Asia (Fig. 6).

As the GI increases, the abundance of *T. vaporariorum* and hence the potential for higher infestations in potato (or other host crops) is expected to increase too. The GI change as shown worldwide for potato growing regions indicates that in most temperate regions of the northern hemisphere, the Andes and the subtropical mountainous regions of Africa, an increase between 1-3 generations can be expected for climate scenarios of the year 2050 (Fig. 7). There are also regions that will experience a decrease of 1-3 generations, especially in tropical and subtropical regions of East Africa and the Middle East, where temperatures have reached the upper temperature threshold of development for this pest (>35°C) (Sanchez et al. 2000). Globally simulated generation indices (Fig. 7) gave reasonable predictions when compared to generation numbers reported in the literature. The number of cycles completed within one year analysis of the future distribution of generations produced per year. For example, 11-15 generations per year were observed in Mexico (Nikolaeva et al. 2010), 10 generations in Spain (BASF 2011) and the Dominic Republic (es.encyclopedia.com/ca/Mosca_blanca, 2010), and 9-11 generations in Chile (Bravo and Lopez 2007). When the establishment index is high (>0.6) and there are 2 to 5 generations per year (as in the Andean region in Cusco), *T. vaporariorum* very likely occurs during the potato growing period and causes economic losses.

Conclusions
This is the first temperature-driven phenology model for *T. vaporariorum* that allowed a detailed analysis of the future distribution of the insect for climate change adaptation planning and integrated pest management.

Bibliography