Rožnovský, J., Litschmann, T., (eds): Mendel a bioklimatologie. Brno, 3. – 5. 9. 2014,
ISBN 978-80-210-6983-1

Model estimation of potential infestation pressure of Codling Moth (*Cydia pomonella*) in condition of changing climate in Slovakia

Juraj Vavrovič[1], Eva Svobodová[2], Mariana Eliašová[1], Ján Kollár[3], Bernard Šiška[1]

1) *Department of Ecology, Faculty of European studies and Regional Development, Slovak University of Agriculture in Nitra, Slovakia*
2) *Institute for Agrosystems and Bioclimatology, Mendel University of Agriculture and Forestry Brno, Czech Republic*
3) *Department of Planting Design and Maintenance, Faculty of Horticulture and Landscape Engineering, Slovak University of Agriculture in Nitra, Slovakia*

Abstract

The occurrence of Codling Moth (*Cydia pomonella*) was estimated on the basis of meteorological data from Climatological Station Network of Slovak republic using CLIMEX model. The conditions of climate change were simulated according to GCM ARPEGE and SRES scenario A1B for three time intervals: 1961-1990, 2021-2050 and 2071-2100. Spatial changes of potential codling moth distribution were estimated using GIS application. As concerning number of generations, during reference period 1961-1990 and period 2021-2050, there were conditions suitable for one generation development. However, during time period 2071-2100, the area where second generation could occur increased to 38% and at 11% of area third generation could occur potentially. For both future time periods, the widening of area affected by codling moth was predicted. During time period 2071-2100 the area with potential occurrence of codling moth increases to 43% comparing to 25% area affected by the moth during the reference period.

Key words: CLIMEX, Codling Moth, number of generation, future distribution

Introduction

Climate change and global warming will have serious consequences for the diversity and abundance of arthropods, and the extent of losses due to insect pests, which will impact both crop production and food security. Presently, it is estimated that the amount of food that insects consume (pre- and post-harvest) is sufficient to feed more than 1 billion people (SHARMA, PRABHAKAR, 2014). Global warning will lead to earlier beginnings and prolongation of growing season in temperate regions and will have pronounced effect on phenology and life-history adaptation in many species (STOECKLI et al., 2012). Concerning insects, changes in the population dynamics are caused by a number of factors, but at least in temperate climates, the temperature is considered to be the most important factor affecting the developmental rate, fecundity and mortality of insects (WORNER, 1992).

The codling moth, *Cydia pomonella* (L.) (*Lepidoptera: Tortricidae*), is one of the most devastating pest insects in apple orchards worldwide (DORN et al., 1999). The pest was originally present in Eurasia; however, during the past two centuries, it has spreading globally with the commercial cultivation of apples and pears and has become one of the most successful pest insects known (THALER et al., 2008). In Slovakia, codling moth belong to the most serious insect pests in orchards and the moth flight is for a number of years regularly monitored at the signalisation stations of the Central Controlling and Testing Institute in Agriculture to emerge signalisation alerts. The forecasting of appropriate time for spraying is based on the pheromone traps records and temperature records (www.uksup.sk). For the purpose of signalisation, the territory of Slovakia is divided to four signalisation zones defined by specific climatic conditions and latitude. But, we must consider that with changing climate the climatic characteristics of these zones will change. MEZEYOVÁ (2007) used the method of calculation the effective temperature sum above 10°C to analyse the potential number of codling moth generations in the condition of changing climate in Slovakia during the period 2001-2100. The model used here works with several climatic characteristics and could thus provide more accurate prediction on potential occurrence of pest in the future.

The main goal of this paper is to estimate how the predicted climate changes may affect the occurrence and emergence of the codling moth in the Slovakia.

Materials and methods

CLIMEX is a simplified computer model that infers the response of a species or biological entity to climate by using its geographical distribution, its seasonal growth pattern and its mortality in different locations (BEDDOW et al., 2010). CLIMEX derives indices that describe the responses of a given species to changes in temperature and moisture. The CLIMEX model uses monthly input data (long-term monthly averages for minimum and maximum air temperatures, relative humidity at 9 a.m. and 3 p.m. and rainfall). The climatological requirements of a given species represent a key element when assessing the suitability of an area for population growth and when determining the stress induced by unsuitable climate conditions. These factors are expressed by the ecoclimatic index (EI), which describes the overall suitability of climate conditions for the establishment and long-term presence of a pest population at a given location (SVOBODOVÁ, et al. 2013). EI values range from 0–100, where EI = 0 indicates climatic conditions that are unfavourable for long-term species occurrence and EI > 30 represents very suitable climatic conditions for species occurrence (SUTHERST, MYAWALD, 1985). The modelled presence of codling moth, as well as several other pests was verified by comparing the observed pest occurrence data with the number of generations in a given modelled area in the central European domain using the 1961 – 1990 reference period. Based on this validated data three thresholds were determined for *Cydia pomonella* describing climate conditions suitable for long-term development of one (EI ≥ 24), two (EI ≥ 39) and three (EI ≥ 48) generations of the pest (SVOBODOVÁ, et al., 2013). The climate data used was derived from the model ARPEGE (SRES A1B). There are three evaluated time periods: the reference time period 1961 – 1990 and two future time periods 2021 – 2050 and 2071 – 2100. The ARPEGE model has been validated in the domain of ERA-40 within the CECILIA project. Spatial estimation of potential codling moth (*Cydia pomonella*) distribution was established by GIS software. As the input data represents an interpolated grid of 10 km x 10 km the outputs were chosen to be displayed in the same grid in order to avoid further data loss to interpolation.

Results

According to CLIMEX model outputs, the conditions suitable for one generation development of *Cydia pomonella* (Figure 1) cover 25.43% of the area of Slovakia for the reference period 1961 – 1990. The most concentrated occurrence of *Cydia pomonella* can be found in Eastern Slovakian Lowlands. The occurrence of 2nd generation development is very rare (0.78%) situated also in the area mentioned above.

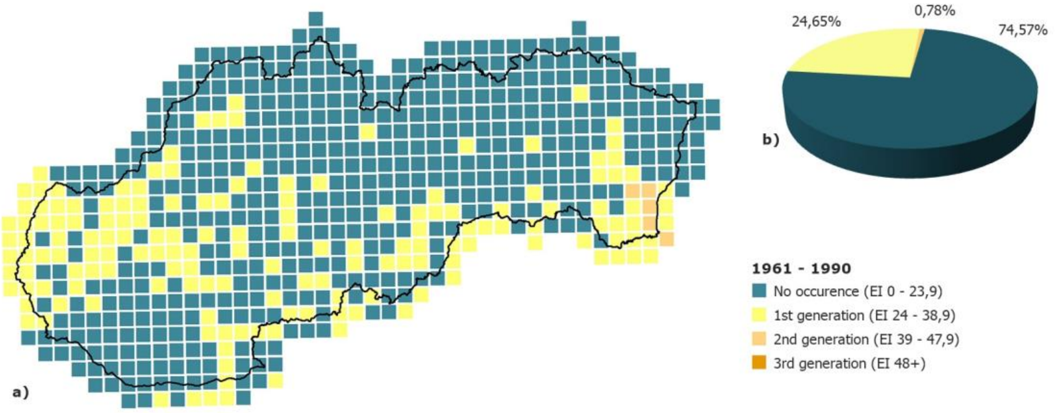

Figure 1: Spatial distribution (**a**) and acreage (%) of area (**b**) providing climatic conditions suitable for 1st, 2nd and 3rd generation by *Cydia pomonella* in the reference period 1961 – 1990 in Slovakia

As for 2021 – 2050, the area of conditions suitable for development of *Cydia pomonella* (Figure 2) extended from 25.43% to 57.52%. On the other hand there is no projection of conditions suitable for development of 2nd generations of *Cydia pomonella* during the period 2021 – 2050. Comparing to reference period, the climatic conditions in Eastern Slovakian Lowland were found to do not provide the conditions suitable enough for even one generation development.

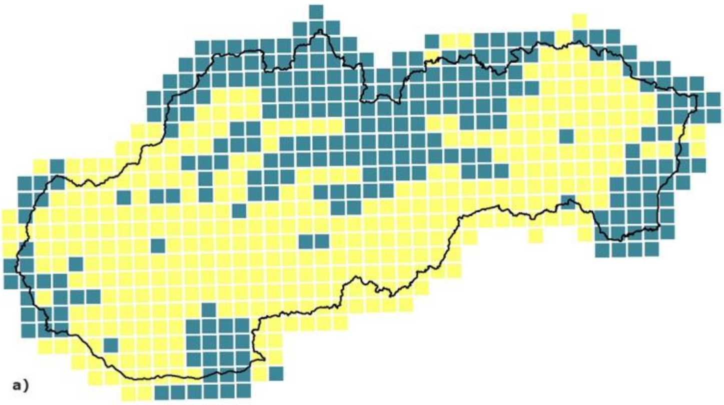

Figure 2: Spatial distribution (**a**) and acreage (%) of area (**b**) providing climatic conditions suitable for 1st, 2nd and 3rd generation by *Cydia pomonella* in the reference period 2021 – 2050 in Slovakia

In 2071 – 2100 the model outputs show a decline of the affected area by 14.73% (from 57.52% to 42.79%) in comparison to the period 2021 – 2050 yet still a significant rise by 17.36% compared to the reference period (from 25.43% to 42,79%). A northward range can be spotted in comparison to the period 2021 – 2050 where the southern regions of previously affected areas are now unsuitable for the development of *Cydia pomonella* while the northern regions show conditions suitable not only for one but for two (37.83%) or three (11.01%) generations development.

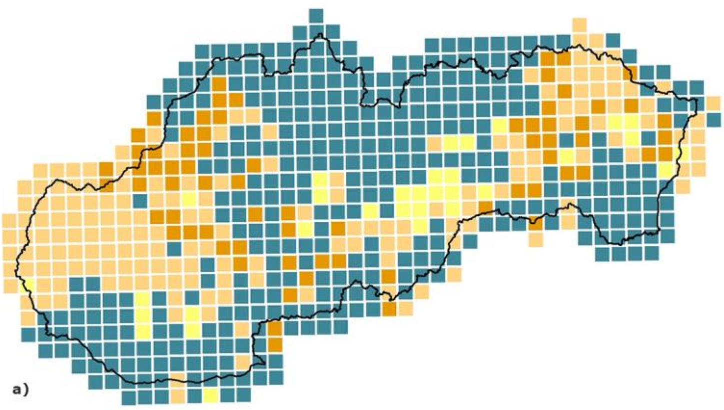

Figure 3: Spatial distribution (**a**) and acreage (%) of area (**b**) providing climatic conditions suitable for 1st, 2nd and 3rd generation by *Cydia pomonella* in the reference period 2071 – 2100 in Slovakia

Discussion

According model outputs, the pest status of codling moth is assumed to be more serious during both future periods modelled. The harmfulness of the pest during the period 2021-2050 will be increasing as the affected area will potentially cover to almost 60% of Slovakia. The affected area is expected to decrease during period 2071-2100, however, there is potential of the occurrence of conditions suitable for 2nd and even 3rd generation development. Mezeyová (2007) analysed the number of potential generations of codling moth in Slovakia using the calculation of effective temperature sum 10°C in the conditions of climate change during the period 2001–2100. The analysis stated increase in number of generations at all thirteen localities analysed. There was the presumption of three generation development and the development of one full generation cycle at the warmest and coldest localities surveyed, respectively (Mezeyová, 2007). According our model output, the occurrence of localities where codling moth would complete full three generations are situated mostly on central to northern part of Slovakia. In all account, the occurrence of 2nd generation will be expected regular at most infested localities in Slovakia in the future.

By 2050, it is thought that there will be an extra 3 billion people to feed. During this timescale, it is likely that insects will increase in numbers and in pest types. Thus, the prediction of changes in geographical distribution and population dynamics of insect pests will be useful for adapting IPM strategies to mitigate the adverse effects of climate change on crop production (SHARMA, PRABHAKAR, 2014). Modelling the range and population dynamics of codling moth is vital in European countries. Irrespective of model or approach they use, the results indicate similar future situation: codling moth will affect wider area then currently, the key developmental stages will occur earlier, prolongation of the codling moth flight period and increasing probability of 3rd generation emergence (HIRSCHI et al., 2012; JUSZCZAK et al., 2013; PAJAČ et al., 2012; SVOBODOVÁ et al., 2013).

As the display of codling moth harmfulness within the territory of Slovakia were assumed being different during the two future periods modelled, the IPM strategies must also differ. To control additional generations of codling moth, an intensification and prolongation of control measures (e.g. insecticides) will be required, implying an increasing risk of pesticide resistances (HIRSCHI et al., 2012). Further to, the log-term insecticide treatments may be responsible for the changes in the behaviour of this pest as during three-year of research an additional third flight period of the codling moths was observed only in the treated orchards in Croatia (PAJAČ et al., 2012). The period 2071-2100 is thus appearing more critical concerning designing appropriate IPM strategies to control codling moth population in Slovakia.

Conclusion

Under future climate condition in Slovakia, the pest importance of codling moth was assumed to increase. The assumption is that codling moth will spread to the northern regions of Slovakia and will affect wider area. There was projected that the climatic condition will be unsuitable for 2nd generation development during the period 2021-2050, but, the range of codling moth may cover almost 60% of the territory of Slovakia. However the acreage of area affected by codling moth will decrease to about 43% of Slovak territory during the period 2071-2100, 2nd generation development was projected become the rule in most affected area. Furthermore, there was assumed that 3rd generation could emerge on about 11% of the territory of Slovakia during this period.

References

BEDDOW, J. M., KRITICOS, D., PARDEY, P. G., SUTHERST, R. W., 2010: Potential global crop pest distributions using CLIMEX. Harvest Choice applications. www.harvestchoice.org.

Dorn, S., Schumacher, P., Abivardi, C., Meyhofer, R.: 1999. Global and regional pest insects and their antagonists in orchards: spatial dynamics. Agric. Ecosyst. Environ. 73, 111–118.

Hirschi, M., Stoeckli, S., Dubrovsky, M., Spirig, C., Calanca, P., Rotach, M.W., Fischer, A.M., Duffy, B., Samietz, J.: 2012. Downscaling climate change scenarios for apple pest and disease modeling in Switzerland. Earth System Dynamics. 3, 33–47, 2012

Juszczak, R., Kuchar, L., Leśny, J., Olejnik, J.: 2013. Climate change impact on development rates of the codling moth (Cydia pomonella L.) in the

Wielkopolska region, Poland. International Journal of Biometeorology (2013) 57:31–44. DOI 10.1007/s00484-012-0531-0

Mezeyová, I. 2007. The proposal of agroclimatic regionalization of chosen apple tree varieties (Malus domestica Borkh.) in condition of changing climate in Slovakia (thesis). Slovak University of Agriculture in Nitra. 132 p.

PAJAČ, I., BARIĆ, B, MIKAC, K.M., PEJIĆ, I.: 2012. New insights into the biology and ecology of Cydia pomonella from apple orchards in Croatia. Bulletin of Insectology 65 (2): 185-193, 2012

Sharma, H.C. - Prabhakar, C.S.: 2014 Impact of Climate Change on Pest Management and Food Security. In: Integrated Pest Management, edited by Dharam P. Abrol, Academic Press, San Diego, 2014, Pages 23-36, ISBN 9780123985293, http://dx.doi.org/10.1016/B978-0-12-398529-3.00003-8.

Stoeckli, S., Hirschi, M., Spirig, C., Calanca, P., Rotach, M.W., Samietz, J.: 2012. Impact of climate change on voltinism and prospective diapause induction of a global pest insect – Cydia pomonella (L.). PLoS ONE 7(4): e35723. doi: 10.1371/journal.pone.0035723

SUTHERST, R. W., MAYWALD, G. F., 1985: A computerised system for matching climates in ecology. Agriculture Ecosystems and Environment 13, 281–299.

SVOBODOVA, E., TRNKA, M., DUBROVSKY, M., SEMERADOVA, D., EITZINGER, J., ŽALUD, Z., ŠTĚPANEK, P.: Pest occurrence model in current climate – validation study for European domain. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 2013, LXI, No. 1, pp. 00–00

THALER R., BRANDSTÄTTER A., MERANER A., CHABICOVSKI M., PARSON W., ZELGER R., DALLA VIA J., DALLINGER R. 2008. Molecular phylogeny and population structure of the codling moth (Cydia pomonella) in Central Europe: II. AFLP analysis reflects human-aided local adaptation of a global pest species. Molecular Phylogenetics and Evolution, 48: 838-849.

WORNER S. P., 1992. Performance of phenological models under variable temperature regimes: consequences of the Kaufmann or rate summation effect. Environmental Entomology, 21 (4): 689-699.

Acknowledgement

This work was supported by the project VEGA 2/0117/13: Evaluation of state and dynamics of biotops using modelling and remote sensing; GIS outputs were created with the help of Vojtěch Lukas from MZLU in Brno, Czech Republic

Summary

Obaľovač jablčný (*Cydia pomonella*) je celosvetovo najvýznamnejší škodca v ovocných sadoch jabloní. Na Slovensku sú vzhľadom na jeho veľký význam

ako škodcu každoročne monitorované jeho nálety na signalizačných staniciach Ústredného kontrolného a skúšobného ústavu poľnohospodárskeho. Cieľom monitoringu je vydávanie tzv. signalizačných výstrah pre ochranu pred škodcom, pričom signalizácia je vykonaná na základe odchytov do feromónových pascí a teplotných údajov. Územie Slovenska je pre potreby signalizácie rozdelené do štyroch signalizačných pásiem definovaných klimatickými podmienkami a nadmorskou výškou. Vplyvom klimatických zmien však musíme predpokladať, že do budúcna sa klimatické charakteristiky týchto pásiem zmenia. Nakoľko klimatické zmeny ovplyvňujú aj populačnú dynamiku a priestorové rozšírenie hmyzu, cieľom príspevku je zhodnotiť, akým spôsobom môžu klimatické zmeny ovplyvniť potenciálnu škodlivosť obaľovača jablčného v podmienkach Slovenska; tu definovanú pomocou dvoch faktorov: priestorového rozšírenia a počtu dokončených generácií v jednom roku. Pre hodnotenie bol použitý matematický model CLIMEX pre územie Slovenskej republiky. Použité klimatické podmienky boli simulované podľa SRES A1B scenára GCM modelu ARPEGE pre tri časové intervaly: 1961–1990, 2021–2050 a 2071–2100. Zmeny priestorového rozpoloženia potenciálneho výskytu obaľovača jablčného boli vyhodnotené cez mapy vygenerované prostredníctvom programu EsriArcGIS. V období 1961–1990 a 2021–2050 boli prevažne podmienky vhodné pre vytvorenie iba prvej generácie hodnoteného škodcu. Bolo vyhodnotené, že počas obdobia 2021-2050 nebudú vhodné podmienky pre vytvorenie druhej generácie škodcu, avšak zasiahnuté územie sa zvýši na takmer 60% plochy Slovenskej republiky. V období 2071–2100 zasiahnuté územie poklesne na 43%. Avšak rozloha, na ktorej by sa mohla vyskytnúť i druhá generácia sa zvýšila z 0% na 38%, pričom na takmer tretine z toho, na 11% z rozlohy, by sa mohla objaviť i tretia generácia. Na základe výstupov modelu môžeme predpokladať, že pri oboch hodnotených časových intervaloch môžeme očakávať nárast jeho škodlivosti. Z porovnania s ostanými podobnými štúdiami vyplýva, že okrem zväčšenia svojho areálu a nárastu počtu generácií sa predĺži aj časový interval, počas ktorého bude potrebné používať chemickú ochranu. Intenzívnejšia chemická ochrana má za následok zmeny v populačnej dynamike škodcu ako aj nárast rezistencie voči insekticídom.

Všetky tieto faktory bude potrebné do budúcna zohľadniť pre vypracovanie efektívnej IPM stratégie pre kontrolu populácií obaľovača jablčného.

Contact:
Ing. Juraj Vavrovič
Department of Ecology, Faculty of European studies and Regional Development, Slovak University of Agriculture in Nitra
Mariánska 10, 949 01 Nitra, Slovakia
00421 037 641 5612, xvavrovic@is.uniag.sk