FINAL REPORT

In this research project, the epidemiological features of key fungal pathogens in fruit crops were investigated under population and within tree levels. Based on this, forecasting models were developed and tested in environmental-benign crop protection systems in order to improve fundamental aspects of disease management. According to this, results of our research project provides new findings on epidemiological and biological features of the key fruit fungal pathogens and their utilizations in PC-based forecasting models in order to increase the sensitivity/accuracy and safety of plant disease control in time and space. Our results were sorted into 5 groups (which were the main objectives of this research project): I) methods for quantitative assessment of inoculum sources and re-examination of disease life cycle stages, II) analysis of individual samples with molecular biology methods in spatio-temporal scales, III) study of weather and biotic factors in relation to disease epidemiology, IV) analysis of epidemiological data with complex mathematical methods and utilize them into PC-based forecasting models, V) testing epidemiological models in environmental-benign crop protection systems.
As key fungal pathogens behave under different roles, three epidemic-control categories were used: a) polycyclic disease with both sexual and asexual cycles of the pathogen requiring regular sprays (here in this research *Venturia inaequalis* and *Blumeriella jaapii*), b) polycyclic disease with mainly asexual cycles of the pathogen requiring regular sprays (here in this research powdery mildews: *Podosphaera* and *Erysiphe* spp.) c) disease with wound and insect related epidemics requiring annual sprays between 5 and 10 (here in this research *Monilinia* spp.).

I) Methods for quantitative assessment of inoculum sources and re-examination of disease life cycle stages

I/i) *Venturia inaequalis* and *Blumeriella jaapii*:

In the case of pome fruits, re-examination of primary life cycle stages for apple scab was made within the tree: first the ascospore dispersal of *V. inaequalis* and subsequent development of scab symptoms were investigated (1) and second the micro-area based spatial distribution of apple scab symptoms within the tree were analyzed under organic disease management (2). Ascospore dispersal was more strongly related to disease development within the tree compared to between tree values as well as the spatial relationships between leaf and fruit symptoms were significantly stronger within the tree compared to between trees. These results suggested that apple scab data obtained within the tree are more suitable to fit epidemiological models.

In the case of sour cherry, saprophytic development of *B. jaapii* was investigated in integrated and organic sour cherry orchards. Our result was the first to demonstrate the cultivar differences in the saprophytic development of *B. jaapii* in integrated and organic sour cherry orchards (3). This epidemiological result suggested that control strategy against *B. jaapii* has to be adjusted to the specific cultivar features of the fungus saprophytic development in both integrated and organic orchards.

I/ii) Powdery mildews:

In the case of powdery mildews, new epidemiological findings were obtained for *Erysiphe necator*: i) we quantified the cumulative spore content in time series analyses ii) we determined the diurnal patterns of trapped spores under various seasonal circumstances and iii) plotted the temporal development of powdery mildew symptoms (4). In addition, we highlighted the lack of disease management oriented epidemiological research for apple powdery mildew in a review paper (5) and we investigated the micro-area based spatial distributions of apple powdery mildew symptoms within the apple trees in an organic orchard (6). This study provided preliminary data on shoot and fruit incidence within the tree and their spatial relationships. Significant relationships were shown between shoot and fruit symptoms which were stronger within the trees compared to between trees (6).

I/iii) Brown rot - *Monilinia* spp.

In the case of wound related pathogens, we demonstrated a new disease life cycle stage (fruit blight) of *M. laxa* and its role in brown rot epidemiology: i) we published first the fruit blight symptoms of *M. laxa* on cherry; ii) then we re-examined the temporal development of *M. laxa* symptoms including blossom blight, fruit blight and fruit rot within the tree in a micro-area scale (7– data obtained from the previous NKFIH K 78399 project but data was analyzed and published during this NKFIH K 108333 project, this is why results included in this NKFIH K 108333 report and not in the previous one).

In addition, within tree spatial distribution of brown rot symptoms on apple fruit was investigated in organic orchards with severe symptoms. We prepared micro-area spatio-temporal analyses for symptomatic patterns, disease aggregation and spatial patterns within the tree canopy (8). Results indicated aggregated patterns within the tree which indicated a disease spread by fruit-to-fruit contact and/or an aggregated pattern of insect damage (8).

We also investigated latent infections caused by *Monilinia* sp. within the tree canopy (9). A positive relationship was confirmed between the incidence of latent infections and the incidence of post-harvest brown rot and between the overall incidence of latent infections and the incidence of latent infections at the different sampling dates in stone fruit. The results suggested possibilities for predicting the incidence of latent fruit infections (9).

II) Analysis of individual samples with molecular biology methods in spatio-temporal scales

We collected *M. laxa* and *M. fructigena* isolates all over the country and we detected spore samples with PCR-based rapid method. In addition, we analyzed genetic diversity of the isolates with ISSR-PCR and PCR-RAPD analyses, and we investigated the genetic structure of *Monilinia* spp. populations (Nei-indices, AMOVA) and their relationship with fungicide sensitivity. In the case of *M. laxa*, 55 and 77 random amplified polymorphic ISSR and RAPD markers were used to assess the genetic diversity and to study the structure of *M. laxa* populations. The analysis of population structure revealed that genetic diversity within locations, inoculum sources and host (HS) accounted for 99% of the total genetic diversity (HT), while genetic diversity among locations, inoculum sources and host represented only 1%. The results obtained in dendrograms were in accordance with the gene diversity analysis. There was relationship between clustering and fungicide sensitivity. In the fungicide sensitivity tests, five isolates were partly insensitive to boscalid+piraclostrobin, cyprodinil, fenhexamid or prochloraz (10).

III) Study of weather and biotic factors in relation to disease epidemiology

From this research project, new findings are reported for the following four factors as components of plant disease epidemics: weather, host, injury, and signal molecules.

III/i) The weather component

In order to improve the practical use of micro-area based apple scab models, we re-examined various weather components (rainfall, relative humidity, Mills' wetness period, temperature and interaction between temperature and relative humidity) for apple scab progress (11). Particularly, the critical weather components of dry and wet years were analyzed on primary inoculum source, incubation period and conidial production of the pathogen (*V. inaequalis*). Results showed that the relationships were the strongest between disease increase and most weather parameters 2 weeks before the symptom appears. Results also demonstrated that weather extremes had an undoubtable effect on the development of scab epidemics which can manifest in the unusual behaviour of the pathogen, resulting in no or extreme disease epidemics.

We also investigated the role of weather components for powdery mildews. Three weather components (temperature, relative humidity, and rainfall) were correlated with mean hourly concentration of *E. necator* ascospores in a 6-year period in two vineyards (4). Significant correlations were found for rainfall and hourly relative humidity for all sites and years.

In addition, brown rot was also involved in the weather component analyses. In order to improve the micro-area based spatial model on *Monilinia* spp., we analyzed the epidemiological features (spore dispersal, diurnal pattern and viability of *Monilinia* spp. conidia) and the relationship with weather components (temperature, relative humidity, and rainfall) in an organic apple orchard (12). Results showed that temperature and relative humidity correlated positively with mean hourly conidia numbers while mean hourly rainfall was negatively but poorly correlated with conidia catches (12).

III/ii) The host component

We investigated the role of host component on powdery mildew epidemics for 27 apple cultivars including resistant, commercial and old cultivars. Categorization of apple cultivars was based on seasonal powdery mildew disease progression in two disease management (integrated and organic) systems over 12 years. Cultivar categorization for powdery mildew showed that season-long disease progress was low for the old; low-to-middle for the resistant; and middle-to-high for the commercial cultivars. A three-parameter logistic function was fitted to the temporal progress data of each classification category. Results demonstrated that the standardized area under the disease progress curves AUDPCS and partially the upper asymptote (Yf), were able to differentiate the five mildew classification categories for both shoot and fruit in both disease management systems (13). As most apple fungal diseases attack both generative and vegetative plant parts, we studied both plant parts in a micro-area scale as a role in disease epidemiology. Results showed that canopy compositions within different quadrats of an individual tree initiates large differences in generative and vegetative plant parts in relation to disease susceptibility (14,15).

III/iii) The injury component

Major injury components for brown rot are insects. Most damaging insects are the moth species which have strong connections to brown rot epidemiology. Moth species can be effectively predicted and we tested female-attractive new traps for possible forecasting purposes. The targeted pest was codling moth (*Cydia pomonella*) and pear ester based lures were tested in comparison with pheromone traps in a multi-year study in Hungary (16). In addition, as insects is considered the major fruit injury factor in organic fruit production, we also determined the relationship between brown rot (*Monilinia* spp.) and injury types (e.g. insect, bird, mechanical injury) in a micro-area scale (17). Results showed insect injuries had the highest correlation coefficients with brown rot incidence among the investigated injury factors (17).

III/iv) The signal molecules component

Salicylic acid (SA) and jasmonic acid (JA), as plant signal molecules, have importance in disease reduction. We performed successful applications of SA and JA treatments for apricot fruit under storage conditions which enhanced the antioxidant properties of treated fruits and improved postharvest fruit quality, including the reduction of fruit decay caused by brown rot (*Monilinia* spp.) (18, 19).

IV) Analysis of epidemiological data with complex mathematical methods and utilize them into PC-based forecasting models

PC-based forecasting models consist of several submodels (moduls) such as i) pathogen, ii) weather, iii) host, and iv) pesticide application and resistance modul. Our new epidemiological data were utilized in one of these moduls.

IV/i) Pathogen modul development

Pathogen modul was improved for *M. laxa* as the role of fruit blight was identified as an essential new element of the life cycle in *M. laxa* epidemiology. In order to use this biological information, i) we determined the epidemiological relationships among blossom blight, fruit blight and fruit rot in two environmentally-benign (integrated and organic) production systems and ii) the strongest correlations between blossom blight and fruit blight were used to improve the pathogen modul for *M. laxa* (7).

IV/ii) Weather modul development

Weather modul was prepared for *E. necator*. We analyzed the weather factors in associations with aerial spore number and disease development, then we fitted Gompertz functions by mixed-effect modelling approach in order to describe the relationship among spore data, disease development and weather factors. Then these functions coupled with the significant correlations on rainfall and hourly relative humidity were utilized in the weather modul of PC-based forecasting models for grapevine powdery mildew (4).

IV/iii) Host modul development

According to model fitting on 27 apple cultivars in integrated and organic production systems, our results showed that parameters of AUDPCS and Yf were suitable as input parameters in disease warning systems in the host modul for measuring host resistance. These parameters were specific for disease management approaches; therefore, they gave us the option to create separated host modul for either integrated or organic apple productions (13).

IV/iii) Pesticide application and resistance modul development

Improvements on IPM require monitoring on sustainability measures. For this, a PC-based decision support system (DEXiPM) was used. We co-designed DEXiPM for pome fruit system (DEXiPM-pomefruit) and we reported the application and effectiveness of this co-designed DEXiPM-pomfruit for measuring sustainability of any IPM systems (20). After this, we used a multicriteria approach for evaluating our innovative IPM systems in pome fruit in

Europe (21). The multicriteria approach assessed environmental risks (SYNOPS), economic effects (Cost/Benefit Analysis) and sustainability impact (DEXiPM-pomefruit). The assessment was made for standard and innovative IPM systems, for different pests (pear psylla and apple codling moth) and diseases (pear brown spot and apple scab). This multicriteria assessment showed that, in general, innovative IPM performed better than the standard one for environmental quality and provided similar yield and pest management without any significant extra costs (21). Above results on moduls of PC-based forecasting models were also applied in the reduction of fungicide use for environmental-benign fruit production (22).

V) Testing epidemiological models in environmental-benign crop protection systems

In this result chapter, disease control modul (the largest component of the PC-based forecasting models) was improved and tested in for integrated and organic management strategies. For designing innovative IPM tools and for analyzing new pest control strategies, we developed a database called PESAP (Pests of Europe and control Strategies for Apple and Pear) in order to optimize environmental-benign control possibilities (23). PESAP, containing 5 major European pomefruit regions, was proved to be useful for designing innovative IPM strategies for pome fruits and was adequate for data transfer into the environmental risk indicator SYNOPS (SYNOPtic assessment of plant protection productS).
The need of PESAP database for designing more environmental-benign control strategies was supported by our critical review, in which we emphasized the role of epidemiology and forecasting in successful control strategies against apple scab in organic production (24).
In order to help the design of a more efficient environmental-benign control strategy, we introduced a biological control agent (*Cladosporium cladosporioides* H39) against apple scab *in vitro* and semi field studies in micro-area scale (25). Then we justified the efficacy of *C. cladosporioides* H39 against apple scab in large fields of several European integrated and organic orchards including the Netherlands, Poland and Hungary (26). Then we recommended *C. cladosporioides* H39 to incorporate into innovative IPM strategy for apple production.

In case of cherry production, we also designed innovative IPM strategy for reducing inoculum sources of *B. jaapii* in fallen infected leaves. This IPM strategy was tested for the efficacy of sanitation practices (urea, lime sulphur, mulch cover) on saprophytic development stages of *B. jaapii* in integrated and organic sour cherry production. Results showed that all urea and lime sulphur treatments significantly reduced the percent survival of *B. jaapii* compared to non-sanitized plots. Treatments that included a mulch cover resulted in a reduction of *B. jaapii* development stages too (3).

After this, we reported the new innovative IPM strategy for European pome fruit production in order to harmonise European integrated fruit protection. This newly designed innovative IPM strategy also included the within tree disease management of key fungal diseases such as apple scab and powdery mildew (27).

Then we evaluated this newly designed innovative IPM strategy *on-farm* and *on-station* in comparison with conventional and standard IPM against apple scab and apple powdery mildew (28). Results showed that scab and powdery mildew incidences were significantly higher in the innovative IPM compared to either conventional or standard IPM. Crop load was similar in the three fruit management approaches, but the first class fruit was significantly higher in the conventional and standard IPM than that of in innovative IPM, indicating a lower fruit quality in the innovative IPM than in the other two systems. Our results suggested that standard IPM can be easily adopted by the IPM growers but innovative IPM is for the future due to low economic sustainability, despite the advanced integration of non-chemical control practices in the innovative IPM (28).

Due to difficulties on economic sustainability and fruit quality demands for IPM, we re-designed utilization of non-chemical control practices in the disease control modul for organic fruit production. Within this, the role of mechanical and physical control in apple orchards as preventative fungal disease management was highlighted (29). According to this, we developed new integrated control strategies for pome fruits against apple scab and powdery mildew in organic orchards. Our study showed a successful integration of four non-chemical control methods (new products of bicarbonates, pathological pruning developed by ourself, sanitation and host resistance) which improved control efficacy within the tree and increased yield in organic apple production (30).

Within the disease control modul, we also developed new integrated control strategies for stone fruits against blossom blight (*M. laxa*) in organic sour cherry orchards. We reported an integrated control approach against brown rot blossom blight in which approved chemical control options (carbonate, sulfur, and copper) were combined with the biological control agent of *Aureobasidium pullulans* in organic cherry production (31).

Our past 20-year results on key fungal diseases in organic production received attention by the American Phytopathological Society (APS), and direct control of airborne diseases and organic apple disease management (including apple scab, powdery mildew and brown rot) were interpreted in two chapters of the book ‘Plant Diseases and Their Management in Organic Agriculture’ published by APS (32,33).

In addition, our European fruit pathology research on innovative IPM and organic disease management strategies were highlighted for Hungarian fruit specialist/growers/stakeholders in publications for domestic readers (C1-C7) and were yearly reported in domestic (C8-C11) and international conferences (C12-C16).

VI) Other results in IF journals from the period of 2013-2017

These publications were only partially or not related to this specific NKFIH K 108333 project but they show a wider scale of research (publication) activity of the principal investigator. Therefore, these papers were NOT GIVEN to publication lists of the NKFIH-OTKA web-page:

- Pusztahelyi T, <u>Holb IJ</u>, Pócsi I. 2015. Secondary metabolites in fungus-plant interactions. **FRONTIERS IN PLANT SCIENCE** 6:573. doi: 10.3389/fpls.2015.00573 **IF:3,948**
- Kiss L, <u>Holb IJ</u>, Rossi V, Cadle-Davidson L, Jeger MJ. 2016. Foreword: Special issue on fungal grapevine diseases. **EUROPEAN JOURNAL OF PLANT PATHOLOGY** 144:693–694. **IF: 1.494**
- Vasileiadis VP, Van Dijk W, Verschwele A, <u>Holb IJ</u>, Vámos A, Urek G, Leskovšek R, Furlan L, Sattin M. 2016. Farm-scale evaluation of herbicide band application integrated with inter-row mechanical weeding for maize production in four European regions. **WEED RESEARCH** 56: 313–322. **IF: 1.517**
- Bársony O, Szalóki G, Türk D, Tarapcsák Sz, Gutay-Tóth Zs, Bacso Zs, <u>Holb IJ</u>, Székvölgyi L, Szabó G, Csanády L, Szakács G, Goda K. 2016. A single active catalytic site is sufficient to promote transport in P-glycoprotein. **SCIENTIFIC REPORTS** 6: 24810; p. 1-16. **IF: 5.228**
- Tarapcsák Sz, Szalóki G, Telbisz Á, Gyöngy Zs, Matúz K, Csősz É, Nagy P, <u>Holb IJ</u>, Rühl R, Nagy L, Szabó G, Goda K. 2017. Interactions of retinoids with the ABC transporters P-

glycoprotein and Breast Cancer Resistance Protein. **SCIENTIFIC REPORTS** 7: Paper 41376. 11 p. **IF: 4.259**

- Vasileiadis V P, Dachbrodt-Saaydeh S, Kudsk P, Colnenne-David C, Leprince F, Holb IJ, Kierzek R, Furlan L, Loddo D, Melander B, Jørgensen L N, Newton A C, Toque C, van Dijk W, Lefebvre M, Benezit M, Sattin M. 2017. Sustainability of European winter wheat- and maize-based cropping systems: Economic, environmental and social ex-post assessment of conventional and IPM-based systems. **CROP PROTECTION** 97: 60-69. **IF: 1.834**
- Furlan L, Vasileiadis V P, Chiarini F, Huiting H, Leskovsek R, Razinger J, Holb IJ, Sartori E, Urek G, Verschwele A, Benvegnù I, Sattin M. 2017. Risk assessment of soil-pest damage to grain maize in Europe within the framework of Integrated Pest Management. **CROP PROTECTION** 97: 52-59. **IF: 1.834**

Research paper publications

1) Holb IJ., Rózsa A., Abonyi F. 2014 Ascospore dispersal of *Venturia inaequalis* and subsequent development of scab symptoms in a Hungarian organic apple orchard. INTERNATIONAL JOURNAL OF HORTICULTURAL SCIENCE 20 (1-2): 35-37.
2) Holb IJ, Lakatos P, Abonyi F. 2015. Micro area based spatial distribution of apple scab in an organic apple orchard. INTERNATIONAL JOURNAL OF HORTICULTURAL SCIENCE 21(3-4): 21-23.
3) Holb IJ, Vasileiadis, VP, Vámos, A. 2014. Effect of sanitation treatment and cultivar on saprophytic development of *Blumeriella jaapii* in integrated and organic sour cherry orchards. **AUSTRALASIAN PLANT PATHOLOGY** 43(4): 439-446. **IF: 1.217**
4) Holb IJ, Füzi I. 2016. Monitoring of ascospore density of *Erysiphe necator* in the air in relation to weather factors and powdery mildew development. **EUROPEAN JOURNAL OF PLANT PATHOLOGY** 144(4): 751-762.; **IF: 1.494**
5) Holb IJ. 2013 Apple powdery mildew caused by *Podosphaera leucotricha*:some aspects of biology. INTERNATIONAL JOURNAL OF HORTICULTURAL SCIENCE 19 (3-4): 19-24.
6) Holb IJ. 2014. Preliminary study on micro area based spatial distribution of powdery mildew in an organic apple orchard. INTERNATIONAL JOURNAL OF HORTICULTURAL SCIENCE 20 (3–4): 35–37.
7) Holb IJ., Szőke S., Abonyi F. 2013. Temporal development and relationship amongst brown rot blossom blight, fruit blight and fruit rot in integrated and organic sour cherry orchards. **PLANT PATHOLOGY** 62: 799–808, **IF: 2.276**
8) Holb IJ., Rózsa, A., Abonyi, F. 2014. Preliminary study on micro area based spatial distribution of *Monilinia fructigena* in an organic apple orchard. INTERNATIONAL JOURNAL OF HORTICULTURAL SCIENCE 20 (3–4): 19–21.
9) Holb IJ. 2015 Harvest and postharvest brown rot of fruit in relation to early latent infection caused by *Monilinia* spp. in Hungary. INTERNATIONAL JOURNAL OF HORTICULTURAL SCIENCE 21 (1-2): 17-20.
10) Fazekas M., Madar A., Sipiczki M., Miklos I., Holb I.J. 2014. Genetic diversity in *Monilinia laxa* populations in stone fruit species in Hungary. **WORLD JOURNAL OF MICROBIOLOGY AND BIOTECHNOLOGY** 30:1879–1892. **IF:1.262**
11) Holb IJ. 2015. Analyses of various weather components of apple scab progress and the effect of dry and wet years on primary inoculum source, incubation period and conidial production of *Venturia inaequalis*. NÖVÉNYTERMELÉS 64:(2): 73-80.
12) Abonyi F, Vámos A, Rózsa A, Lakatos P, Holb IJ. 2015. Spore dispersal, diurnal pattern and viability of *Monilinia* spp. conidia and the relationship with weather components in an

organic apple orchard. INTERNATIONAL JOURNAL OF HORTICULTURAL SCIENCE 21(3-4): 17-19.

13) Holb IJ. 2017. Categorization of apple cultivars based on seasonal powdery mildew disease progression in two disease management systems over 12 years. **TREES-STRUCTURE AND FUNCTION** 31(6): 1905-1917. **IF: 1.842**

14) Csihon, Á., Holb, IJ., Gonda, I. 2015. Growing characteristics of apple cultivars and canopies. INTERNATIONAL JOURNAL OF HORTICULTURAL SCIENCE 21 (1-2): 7-10.

15) Csihon, Á, Holb, IJ, Gonda, I. 2015. Evaluation of generative accomplishment of new apple cultivars in Hungary. INTERNATIONAL JOURNAL OF HORTICULTURAL SCIENCE 21 (1-2): 11-16.

16) Tóth M., Jósvai J., Hári K., Pénzes B., Vuity Zs., Holb I., Szarukán I., Kecskés Zs., Dorgán-Zsuga I., Konczor S., Voigt E. 2014. Pear ester based lures for the codling moth *Cydia pomonella* L. – A summary of research efforts in Hungary. ACTA PHYTOPATHOLOGICA ET ENTOMOLOGICA HUNGARICA 49 (1): 37–47.

17) Abonyi F, Vámos A, Lakatos P, Rózsa A, Holb IJ. 2016. Fruit injury in organic fruit production and its relationship to brown rot caused by *Monilinia* spp. INTERNATIONAL JOURNAL OF HORTICULTURAL SCIENCE 22:(1-2): 7-9.

18) Ezzat A, Ammar A, Szabó Z, Nyéki J, Holb IJ. 2017. Postharvest treatments with methyl jasmonate and salicylic acid for maintaining physico-chemical characteristics and sensory quality properties of apricot fruit during cold storage and shelf-life. **POLISH JOURNAL OF FOOD AND NUTRITION SCIENCES** 67(2): 159-166. **IF: 1.276**

19) Ezzat A, Ammar A, Szabó Z, Holb IJ. 2017. Salicylic acid treatment saves quality and enhances antioxidant properties of apricot fruit. **HORTICULTURAL SCIENCE** 44(2): 73-81. **IF: 0.566**

20) Alaphilippe A., Angevin F., Buurma J, Caffi, T., Capowiez Y, Fortino G., Heijne H., Helsen H., Holb I., Mayus M., Rossi, V., Simon S., Strassemeyer J. 2013. Application of DEXiPM® as a tool to co-design pome fruit systems towards sustainability. IOBC-WPRS Bulletin, 91: 531-535.

21) Caffi T, Helsen H H M, Rossi V, Holb IJ, Strassemeyer J, Buurma J S, Capowiez Y, Simon S, Alaphilippe A 2017. Multicriteria evaluation of innovative IPM systems in pome fruit in Europe. **CROP PROTECTION** 97: 101-108. **IF: 1.834**

22) Holb I. 2018. A növényvédelmi előrejelzés a fungicides kezelések csökkentésének szolgálatában. NÖVÉNYVÉDELEM 54 (1): 14-17.

23) Mayus M., Alaphilippe A., Buurma J., Caffi T., Capowiez Y., Fortino G., Heijne B., Helsen H., Holb I., Rossi V., Simon S., Scheer C., Trautmann M., Strassemeyer J. 2013. The database PESAP to design pomefruit protection strategies. IOBC/WPRS Bulletin, 91: 551-555.

24) Holb I.J. 2013. Apple scab management in organic fruit orchards: epidemiology, forecasting and disease control strategies. ACTA HORTICULTURAE 1001: 223-234.

25) Köhl J, Scheer C, Holb IJ., Masny S, Molhoek WML. 2015. *Cladosporium cladosporioides* H39: A new biological control agent for apple scab control. IOBC-WPRS Bulletin 110:187-189.

26) Köhl J, Scheer C, Holb IJ, Masny S, Molhoek W. 2015. Toward an integrated use of biological control by *Cladosporium cladosporioides* H39 in apple scab (*Venturia inaequalis*) management. **PLANT DISEASE** 99: 535-543. **IF: 3.02**

27) Heijne B, Helsen HHM, Caffi T, Rossi V, Strassemeyer J, Köhl J, Riemens MM, Alaphilippe A, Simon S, Capowiez Y, Holb IJ, Buurma JS, Hennen WHGJ. 2015. PURE progress in innovative IPM in pome fruit in Europe. ACTA HORTICULTURAE 1105: 383-390.

28) Holb IJ, Abonyi F, Buurma J, Heijne B. 2017. On-farm and on-station evaluations of three orchard management approaches against apple scab and apple powdery mildew. **CROP PROTECTION** 97: 109-118. **IF: 1.834**

29) Holb IJ. 2016. Mechanical and physical control in apple orchards as preventative fungal disease management. INTERNATIONAL JOURNAL OF HORTICULTURAL SCIENCE 22:(1-2): 19-21.

30) Holb IJ, Kunz S. 2016. Integrated control of apple scab and powdery mildew in an organic apple orchard by combining potassium carbonates with wettable sulfur, pruning and cultivar susceptibility. **PLANT DISEASE** 100 (9): 1894-1905. **IF: 3.192**

31) **Holb IJ**, Kunz S. 2013. Integrated control of brown rot blossom blight by combining approved chemical control options with *Aureobasidium pullulans* in organic cherry production. **CROP PROTECTION** 54: 114-120 **IF: 1.402**

32) Holb IJ, Heijne B, Tamm L. 2015. Organic apple disease management. In: Finckh MR, van Bruggen AHC, Tamm L (szerk.) Plant Diseases and Their Management in Organic Agriculture. 414 p. USA: APS Press, 2015. pp. 319-334.

33) Tamm L, Speiser B, Holb IJ. 2015. Direct control of airborne diseases. In: Finckh MR, van Bruggen AHC, Tamm L (szerk.) Plant Diseases and Their Management in Organic Agriculture. 414 p. USA: APS Press, 2015. pp. 205-216.

Conferences and publications for domestic implementation

C1) Vámos A, Holb I. 2013. Növényvédelem. pp. 149-163. In: Gonda I, Apáti F. (szek): Versenyképes almatermesztés. Szaktudás Kiadó Ház Zrt., Budapest, p. 317.

C2) Holb I. 2014. Védekezési lehetőségek az alma ventúriás varasodás ellen nem kémiai módszerekkel. MEZŐHÍR 18 (2): 50-51.

C3) Holb I. 2014. Gondolatok az almafalisztharmatról: járványjellemzők és védekezés kapcsolata. MEZŐHÍR 18 (6): 76-77.

C4) Holb I. 2015. A gyümölcsösök környezetkímélő növényvédelmének helyzete, eredményei és kihívásai. DEBRECENI SZEMLE 2015(2): 113-124.

C5) Holb I. 2016. A fontosabb gombás betegségek elleni védekezés. In: Nyéki J., Szabó T., Soltész M. (szerk.). Meggy: a jövedelmező intenzív termesztés alapjaival. 425 p. Újfehértó: Újfehértói Gyümölcstermesztési Kutató és Szaktanácsadó Nonprofit Közhasznú Kft., 2016. pp. 241-246. (ISBN:978-963-12-6523-1)

C6) Holb I. 2016. Növényvédelem a bioültetvényekben. In: Nyéki J., Szabó T., Soltész M. (szerk.). Meggy: a jövedelmező intenzív termesztés alapjaival. 425 p. Újfehértó: Újfehértói Gyümölcstermesztési Kutató és Szaktanácsadó Nonprofit Közhasznú Kft., 2016. pp. 259-262. (ISBN:978-963-12-6523-1)

C7) Holb IJ. 2017. Az alma ventúriás varasodása elleni integrált védekezés nehézségei. In: Magyar Növényvédő Mérnöki és Növényorvosi Kamara Magyar Növényvédő Mérnöki és Növényorvosi Kamara (szerk.) XII. Növényorvosi Nap Kiadványa. Konferencia helye, ideje: Budapest, Magyarország, 2017.11.08 Agroinform Kiadó, pp. 77-78.

C8) Holb I. 2014. Az alma ventúriás varasodás, az alma moniliniás gyümölcsrothadás és az almafalisztharmat járványdinamikája integrált és ökológiai ültetvényekben és hasznosítása a növényvédelmi prognosztikában. 60. Növényvédelmi Tudományos Napok, Összefoglalók. Budapest, pp. 59.

C9) Holb I, Abonyi F. 2015. *Monilinia* gombafajokon végzett mikro-area térbeli-időbeli járványkutatások részeredményei meggyültetvényekben. 61. Növényédelmi Tudományos Napok. 2015. február 17-18. Összefoglalók: p. 48. ISSN 0231 2956

C10) Holb I, Kunz S, Köhl J, Abonyi F. 2016. Mikro-area térbeli-időbeli járványkutatások részeredményei és szerepük a ventúriás varasodás és az almafalisztharmat elleni integrált védekezésben. 62. Növényvédelmi Tudományos Napok. Összfoglalók: 101 p.

C11) Holb I. 2018. A növénykórokozó gombák járványainak főbb sajátosságai a hatékony előrejelzés és a környezetkímélő védekezés összefüggésében. 64. Növényvédelmi Tudományos Napok. 2018. február 20-21. Összefoglalók: p. 18.
C12) Holb I. 2014. *Venturia* spp. en cultivos de paras y manzanas respetuosos con le medio embiente: de la epidemiología a la gestión de las enfermedades. Phytoma 256: 20. Special issue for abstracts of the SmartFruit IPM Intenational Congress, 2-4 February 2014, Barcelona, Spain.
C13) Köhl, J.; Scheer, C.; Holb, I.J.; Masny, S.; Molhoek, W.M.L. 2014. Options for the use of the biological control agent *Cladosporium cladosporioides* H39 in IPM strategies for apple scab control. Cracow, Poland: 11th Conference of the European Foundation for Plant Pathology, 8-13 September 2014,
C14) Köhl, J.; Scheer, C.; Holb, I.J.; Masny, S.; Molhoek, W.M.L. 2014. Anwendung des Antagonisten *Cladosporium cladosporioides* H39 zur biologischen Bekämpfung von Apfelschorf. In: 59. Deutsche Pflanzenschutztagung "Forschen – Wissen – Pflanzen schützen: Ernährung sichern!" 23. bis 26. September 2014, Freiburg. - Julius-Kühn-Archiv 447 (2014). - ISSN 1868-9892 Julius Kühn-Institut, 2014 - p. 328
C15) Köhl J, Scheer C, Holb IJ, Masny S, Molhoek WML. 2015. Biological control of apple scab (*Venturia inaequalis*) by *Cladosporium*. In: Conference on IPM Innovation in Europe. Poznan, Poland, 14-16 January 2015. Book of Abstract p. 32.
C16) Delval P, Alaphilippe A, Caffi T, Heijne B, Holb I, Strassemeyer J, Buurma J,Helsen H, Simon S, Capowiez Y, Rossi V, Hennen W. 2015. PURE: results and lessons from the 2011-2015 FP7 program on pesticide use and risk reduction the pome fruit experience. 5th International conference on alternative methods of crop protection. 11-13 March 2015, Lille, France. Book of Abstract p. 23.