Malus and *Pyrus ex situ* germplasm collection as a raw material source for future breeding challenges and landfill for the development of modern technologies

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Introduction

The conservation of horticultural biodiversity is an issue of increasing importance due to the acceleration of climate and societal change. Climate change has contributed to the spread of new pathogens or increased the activity of known pathogens. On the other hand, public pressure calls for a reduction in the use of pesticides and the production of products as healthy as possible, which is particularly important for fruit crops. *Ex situ* collections of genetic resources can serve as a source of raw material, offering environmentally adapted accessions with specific characteristics. *Malus* and *Pyrus* are important temperate-zone genera, include widely grown fruit species worldwide and Latvia, and are commercially among the most important fruit crops. This is also evidenced by the representation of these genera in the germplasm collections - *Malus* and *Pyrus* are the most widely represented in the collection of the Institute of Horticulture, Latvia and includes more than 1000 accessions of *Malus* and more than 400 accessions of *Pyrus*, of which 460 and 169, respectively are a part of national genetic resources (GR). The collection includes cultivars and hybrids bred in Latvia, landraces, introduced cultivars cultivated for a long-time in Latvia and samples of crop wild relatives collected in Latvia. Therefore, this report aimed to demonstrate the applicability of the *Malus* and *Pyrus ex situ* collections to select resistance donors for resistant cultivar breeding and develop new digital tools for the early identification and evaluation of diseases.

Materials & Methods

The experimental data were collected in the period from 2013 to 2015 at the genetic resources collection field of the Institute of Horticulture (LatHort), located at Dobele (N: 56°36'39" E: 23°17'50"), Latvia. The study included 270 apple and 192 pear genotypes evaluated according to VINQUEST methodology (http://www.vinquest.ch). Apple and pear scab symptoms at different stages of development were photographed using a mobile phone, annotated, marking places of symptoms and adding information about the severity of the scab. The resulting annotated images were used in a neural network application that performed automated disease recognition.

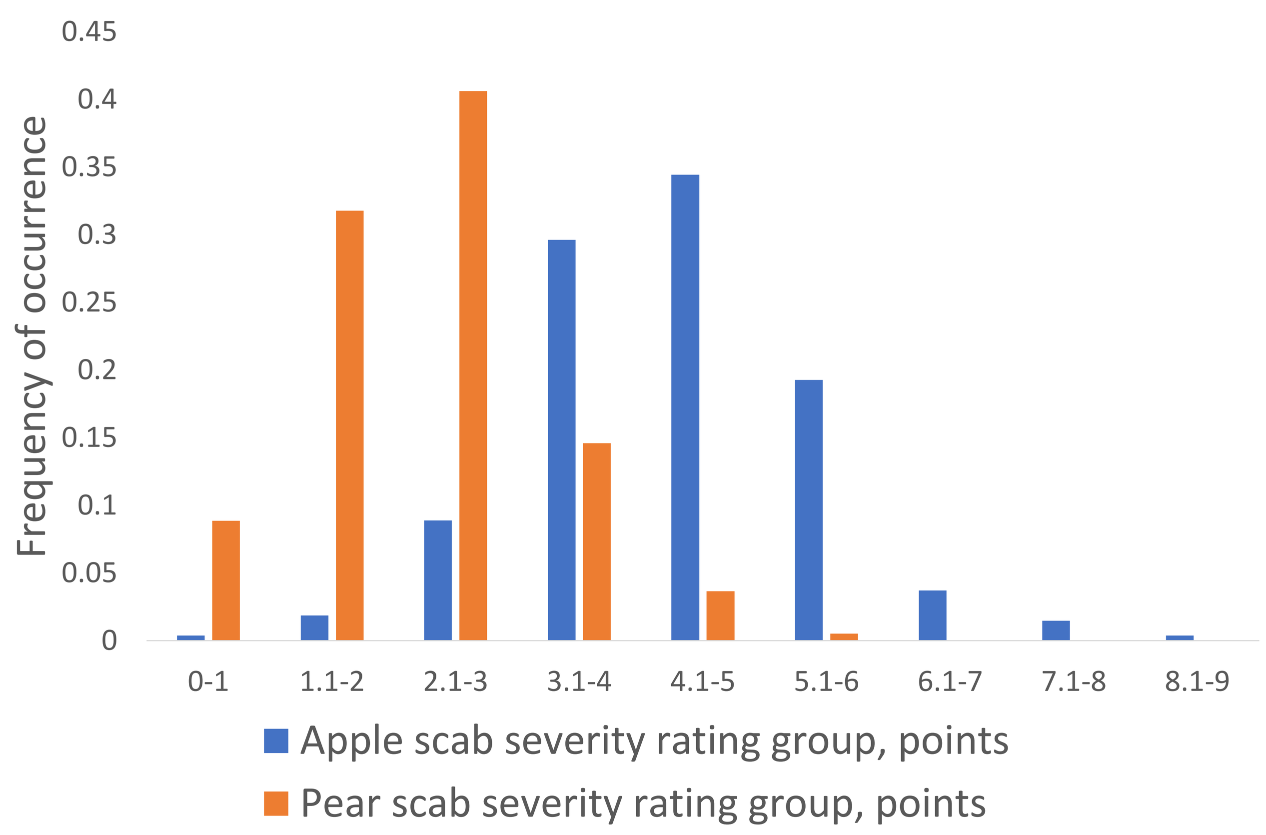

Fig. 1 Frequency of scab severity scores on apple and pear leaves

Results

The evaluation of the *ex situ* germplasm collection of apples and pears on the scab severity allowed us to identify new resistant genotypes, characterize them, and define the potential breeding sources. Genotypes grown in Latvia are resistant to scab, especially pears (Fig. 1), as most severity scores are low (4.1-5 points for apples, 2.1-3 points for pears).

Because of scab-infected apple and pear image collection, a set of open-access datasets of annotated images was created and published in the *Kaggle* repository (*AppleScabLDs*) and can be used globally for the deep learning (DL) approach to develop solutions for the smart farming (Fig. 2). Severity data were summarized and combined with other data types (molecular marker data, pictures of disease symptoms, environment) by developing an ontology for further integration into a decision-making system based on neural network solutions.

Thereby, *ex situ* germplasm collections serve as a link between the conservation of heritage, direct use in fruit-growing, a potential source for breeding and as a landfill for the development and application of modern technologies in horticulture (including sensing technologies, software applications, communication systems, telematics and positioning technologies, hardware and software systems, data analytics solutions and knowledge linking biological information to data technologies).

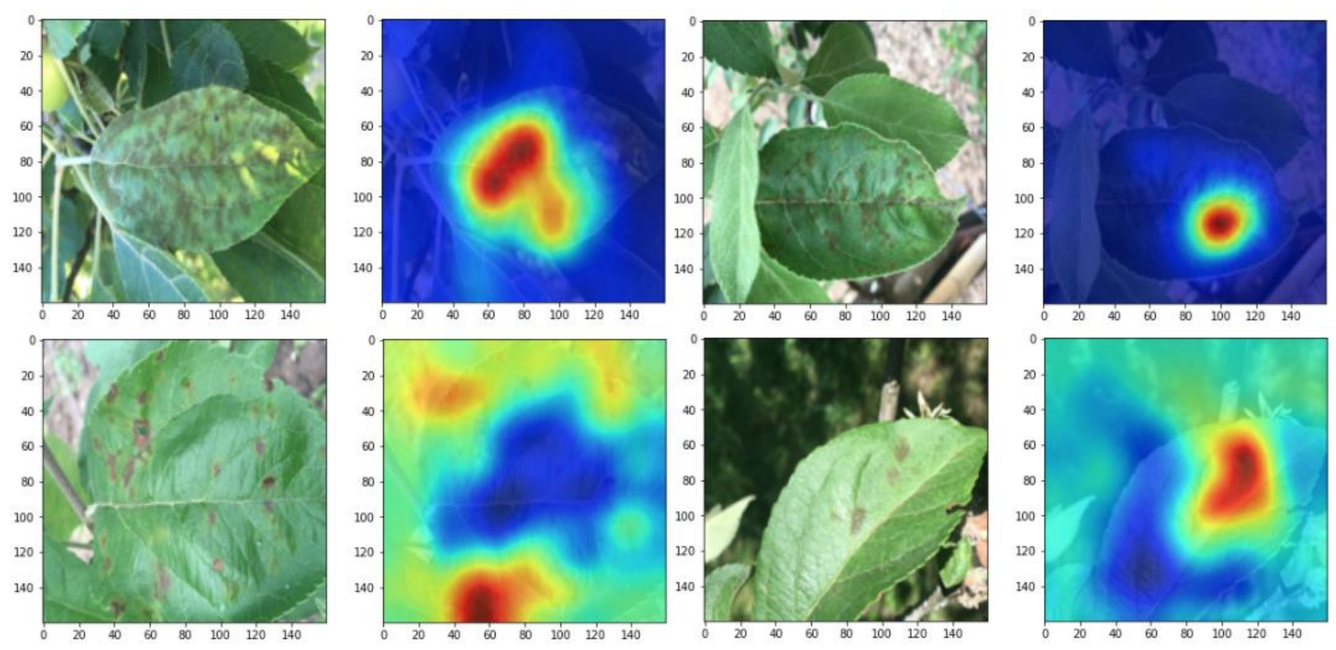

Fig. 2 Quality control of apple scab early detection: image areas with increased neural network attention

Conclusions

- The *ex situ* germplasm collection is a good source for selecting resistance donors and allows an understanding of the structure of the studied plant populations and the regularities of plant-pathogen interactions.
- The *ex situ* collection is a good landfill for developing and validating new technologies due to the great diversity in a limited and accessible area.

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FLPP FUNDAMENTAL AND APPLIED RESEARCH PROJECTS

Supported by Latvian Council of Science funded project "Application of deep learning and datamining for the study of plant-pathogen interaction: the case of apple and pear scab", project No. lzp-2019/1-0094.