A ResNet-CNN for accurate quantification of grapevine leaf hair

Malagol, Nagarjun; Rao, Tanuj; Schwandner, Anna; Töpfer, Reinhard; Hausmann, Ludger*

Julius Kuehn Institute (JKI), Institute for Grapevine Breeding Geilweilerhof, Siebeldingen, Germany
*ludger.hausmann@julius-kuehn.de

Abstract

The leaf hair density on the abaxial surface of *Vitis* species varies greatly. Generally, a dense indumentum is an effective protective mechanism to prevent damage from pests and pathogens, provide shelter for predatory species and influences transpiration. Most importantly for grapevine, this physical defence mechanism based on hydrophobicity prevents the infection by pathogens that rely on the presence of water for their spore germination. In particular, the entry of the oomycete *Plasmopara viticola* into the stomata on the lower side of the leaf is hampered. Leaf hair density is a complex morphological trait and is difficult to phenotype due to the lack of reliable and accurate tools for quantification. However, precise quantitative data are necessary to elucidate the genetic factors of leaf hair formation and density by e.g. quantitative trait locus (QTL) mapping. Many advanced Machine Learning (ML) models have been successfully implemented in plant morphological trait classification. Therefore, we trained a Residual Networks based Convolutional Neural Network (ResNet-CNN) model for accurate and precise quantification of leaf hair with an overall model accuracy of 95.41%. Performance evaluation of the model in correlation with experts evaluation data yielded a significant correlation of R=0.98 and R=0.92, and root-mean-square error values of 8.20 and 14.18, respectively. Furthermore, subsequent evaluation of a set of six varieties segregating for leaf hair density by experts and non-experts revealed a significant level of bias in terms of absolute error for non-experts. Moreover, validation with a panel of novice evaluators resulted in considerable over- and underestimation of the trait. In conclusion, the developed ResNet-CNN has significant potential for enhancing objective phenotyping accuracy for the leaf hair density, allowing a more precise examination and ultimately making it accessible for grapevine breeding.

Keywords: *Vitis*, trichome, machine learning, ResNet CNN, phenotyping, quantification