Effects of *(Ips typographus, L.)* green attack on leaf properties

The increasing number of severe bark beetle outbreaks in coniferous forests of Europe over the last few decades has led to extensive economic losses to the forest industry. Beside the economic losses, the outbreak of bark beetle has resulted in significant ecological changes, regarding forest structure and composition, wildlife habitats, and it has also caused the degradation of the large areas of the forests. Therefore, this lead to an increase research interest to understand the dynamics and to improve management of *(Ips typographus, L.)* outbreaks. Early detection of infestation (the so-called “green attack”) is important to a forester who want to minimise economic loss and preclude a mass outbreak due to this threat. The green attack is the initial stage of bark beetle infestation when the leaves remain green and do not change colour, so this stage is not detectable by human eye. Traditionally, foresters perform field surveys to identify the infested trees; such surveys are very laborious, costly and therefore cannot apply to large areas. Remote sensing has the potential to detect pest infestations over large areas and in relatively short periods of time. Exploiting remotely sensed data allows monitoring the changes in leaf and canopy properties before and after insect infestation. Until now, the utilisation of remote sensing for the monitoring and detection of bark beetles by forest managers has mainly focused on the last two attack stages and has achieved a high degree of accuracy (i.e. the red and grey attack) where changes in canopy colour have been used as an indicator to detect infestations. However, detecting the last two stages of bark beetle attack are not sufficient for an appropriate management of infested trees, as during the red attack stage the beetles have already left their host trees and started to attack new trees. Therefore, mangling the beetle outbreak during these two stages will have no effect in preventing outbreaks. To give value for forest management, the detection of infestation should be early enough to allow timely intervention and minimise the future outbreak.

**Research objective**

In this study, the early detection of bark beetle green attack was investigated by examining foliar biochemical and spectral properties (400 – 2000 nm) and assessing whether infestation affects the retrieval of foliar biochemical properties from hyperspectral measurements.

**Material and methods**

1. Field survey was conducted in the Bavarian Forest National Park (BFNP) - Germany, to collect leaf samples from healthy and infested trees. A crossbow was used to shoot an arrow attached to a fishing line at a branch with sunlit leaves. Over all 66 and 54 sam ples were collected for healthy and infested trees, respectively.

2. Reflectance spectra were measured from each sample using an ASD FieldSpec-3 Pro FR spectrometer equipped with and ASD RT3-ZC integrating sphere. Chlorophyll concentration was measured from fresh leaves using spectrophotometer following the Lichtenthaler (1987) method using acetone (v 100%). Nitrogen concentration was measured from dried leaves using an organic elemental analyser.

3. The significant of differences (p ≤ 0.5) in leaf proper ties between healthy and infested foliar was determined using student’s t-test.

4. To explorer, the impact of bark beetle green attack on foliar spectral reflectance in regard to chlorophyll and nitrogen concentration. Variable importance in the projection (VIP) was calculated from partial least square regression (PLSR).