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UAV-based hyperspectral monitoring of peach trees as affected by Silicon applications and water stress status

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Abstract.

The use of reduced doses of Silicon (Si) has been shown to improve crop tolerance to biotic and abiotic stresses, including water stress, which is a common stress to young peach trees due to the lack of irrigation during their first two years. The use of hyperspectral information has proven to be a suitable nondestructive method for detecting stresses, such as nutrient deficiencies, water scarcity or disease. We present a nondestructive remote sensing method to evaluate and monitor the impact of different Si and water treatments on the spectral response of peach trees using UAV-based hyperspectral imagery. The preliminary results showed significant differences in peach canopy hyperspectral profiles mainly in the green and near-infrared regions according to Si treatments and water regimes applied.

Keywords.

Remote sensing, Unmanned Aerial Vehicle, crop production, fertirrigation, object-based image analysis (OBIA).

Introduction

Previous research has shown that the application of reduced doses of Silicon (Si) improves crop tolerance to biotic and abiotic stresses, including water stress (Fernández-Escobar 2019). Water scarcity is common in commercial young peach trees because irrigation is not usually applied during their first two years (Zambrano-Vaca et al. 2020). Hyperspectral information in the visible- and near infrared range have proved the capabilities to detect early changes in plant physiology due to biotic and abiotic stresses, as nutrient deficiencies or disease (de Castro Megías et al. 2021). Therefore, this study used aerial images to monitor the impact of different Si treatments and water regimes on the hyperspectral response of peach trees.

Materials and Methods

The experiment was carried out with 60 young (under 1 year old) peach trees located at the University´s Musser Fruit Research Center (Seneca, SC, USA). The trees were planted on pots and placed in an umbraculum, which were moved outdoors during image acquisition. The experimental design consisted of 30 water-stressed trees and 30 irrigated trees, so each group was divided into 5 subsets of 6 trees each, to which doses of 2 and 4 ppm of two Si products (pure Si at such concentrations and a commercial brand SI) at several times throughout the study, plus the remaining subset being the control. Information on the nutrient and water tree status was frequently measured with leaf analysis and a Scholander pressure chamber, respectively.

The aerial images were collected with the Senop HSC-2 hyperspectral camera mounted in a hexacopter drone model DJI Matrice 600 Pro on September 19th, October 2nd and November 13th, 2019 (Figure 1a). This camera took the images at 20 m altitude and 500-900 nm of spectral range, 1.0 nm of bandwidth, 1 megapixel of resolution (1,024 x 1,024 pixels), and 12 bits of radiometric resolution. The images had a spatial resolution of 2.5 cm/pixel. The processing of the hyperspectral images involved the following phases: 1) image radiometric correction and transformation of raw pixel values to top-of-canopy reflectance, 2) image segmentation and classification of individual trees, 3) retrieving of tree canopy hyperspectral signatures, and 4) analysis of hyperspectral data.

Results

A customized object-based image analysis (OBIA) algorithm was applied to automatically isolate each peach treatment and to retrieve spectral information of pure tree pixels (figure 1b). The peach experiment did document sufficient reflectance differences between extreme treatments at the first date, mainly in the green and near-infrared regions. These results are in agreement with those of de Castro et al. (2021), who reached spectral differences caused by peach rust disease development in those spectral regions, therefore confirming the potential of using hyperspectral camera information to examine and monitor factors affecting peach cultivation.

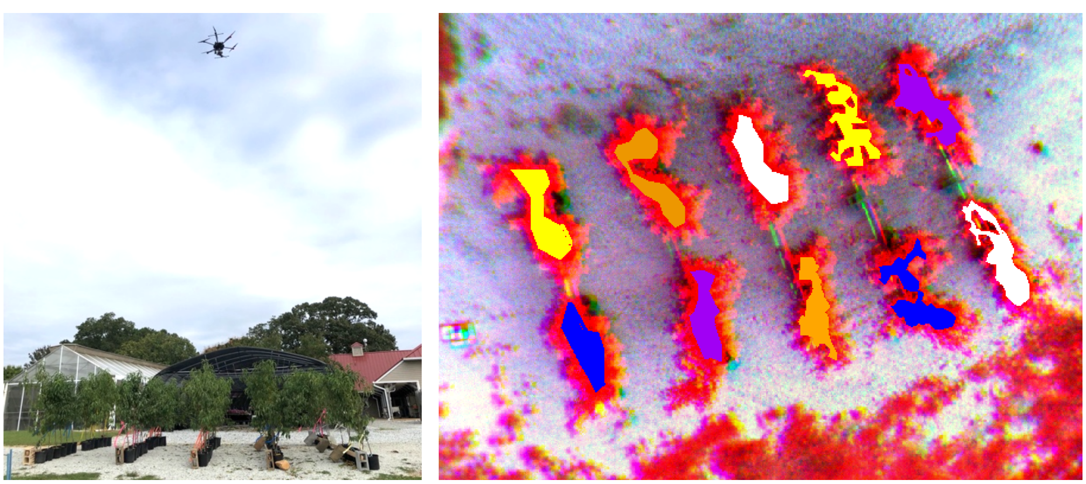

Fig 1. UAV capturing the hyperspectral images of the peach experiment (a) and isolation of each treatment with an OBIA algorithm (b).

The largest differences were observed between Non-stressed trees without Si application (control trees) and non-stressed trees with pure Si application at a dose of 2 ppm in the green region, and between stressed trees with commercial Si application at a dose of 2 ppm and non-stressed trees with pure Si application at a dose of 4 ppm in the infrared region (figure 2).

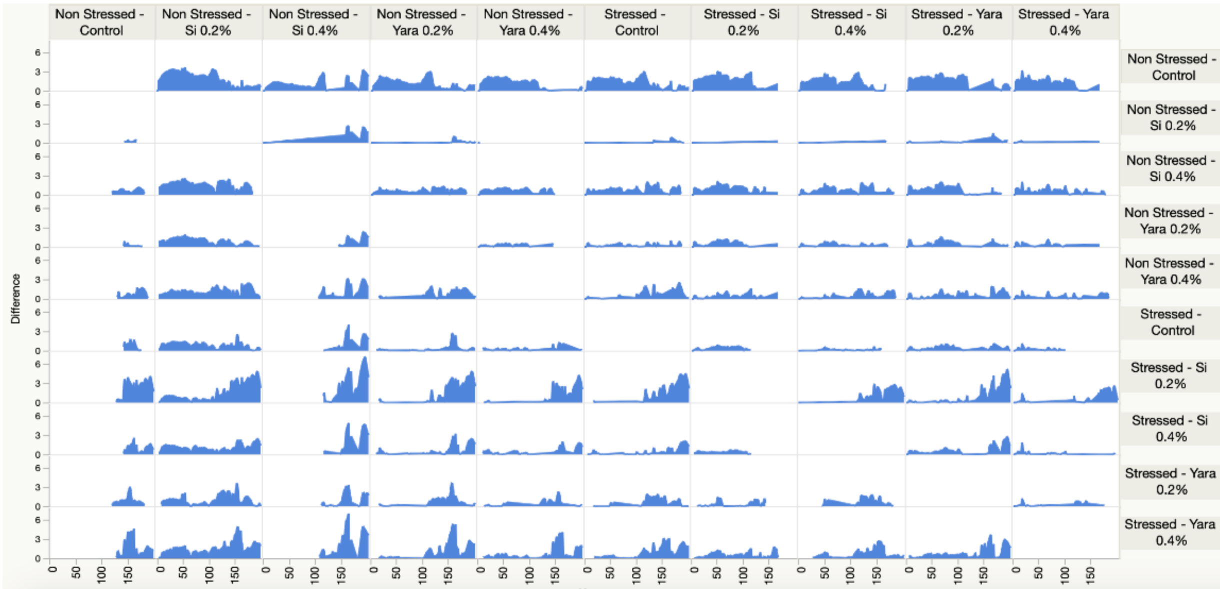

Fig 2. Spectral differences as affected by peach water regime and Silicom treatment

Conclusion

UAV-based hyperspectral images showed potential to evaluate the effect of different Si treatments and water regimes in young peach trees, mainly in the green and near-infrared spectral regions. Further statistical multi-variable analysis will enable the definition of relevant wavelengths or vegetation indices to be used as indicators of Si nutrient content and water stress status during the early stages of peach plantations.

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