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Title of thesis: Impact of light-emitting diodes on the growth and development of *Spinacia oleracea* L.: Assessment via morphological, physiological and image-based attributes

Abstract

Light plays an important role in regulating the morphology and physiology of plants. Various studies have reported the impact of red:blue photon flux ratio (PFR) on plant growth and nutrient content. However, studies investigating the influence of red:blue PFR on the underlying physiological processes are limited. The present study was carried out to assess plant growth, photosynthetic attributes, nitrate assimilation, metabolite profile, oxidative stress and antioxidant defense for spinach (*Spinacia oleracea* L. cv. All Green) grown under red:blue PFRs of 100% red, 75% red + 25% blue, 50% red + 50% blue, 25% red + 75% blue and 100% blue provided by customized light-emitting diode (LED) panels. Canopy and leaf digital-images were analyzed for non-invasive assessment of spinach growth and health status under the different light treatments. It was observed that steady growth under blue + red combined LED treatments co-occurred with stable photosynthetic activity and reduced oxidative stress. Subdued photosynthetic activity under monochromatic red light was associated with arrested growth. Presence of blue photons was favorable for eliciting enzymatic antioxidant defense responses. Contents of antioxidant compounds and non-enzymatic antioxidant activity were increased under 50-100% blue light. However, the antioxidant machinery was unable to ameliorate the excessive oxidative stress under 100% blue light treatment resulting in suboptimal plant growth. Canopy cover information obtained from canopy images revealed that equal red:blue PFR was most suitable for spinach growth. Multivariate data analysis of leaf digital-image features allowed the detection of healthy, viz. 75% red + 25% blue to 25% red + 75% blue LED treated, and stressed, viz. 100% red and 100% blue LED treated, plants. Amongst the different trichromatic coordinates obtained from leaf digital-images, viz. RGB (red, green and blue), *rgb* (normalized red, green and blue), HSI (hue, saturation and intensity), CIE (Commission Internationale de l'Eclairage) $L^*a^*b^*$, CIE-XYZ and CIE-xyY, relative chlorophyll content estimated via multiple linear regression of CIE $L^*a^*b^*$ values was the most accurate.

Keywords: Light-emitting diodes (LEDs), photosynthetic pigments, chlorophyll fluorescence, nitrate assimilation, metabolite profiling, reactive oxygen species (ROS), antioxidant defense, image analysis, RGB color space, *Spinacia oleracea* L.