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Digital Image Analysis: an innovative method to assess nutritional status of common wheat

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Common wheat (*Triticum aestivum* L.) is one of the most important crops, whose profitability is linked to the increase of quality characteristic and input optimization. The main parameter in determining wheat price is grain protein content, which is strongly influenced by nitrogen (N) availability during advanced stages of development. Therefore, N application between flag leaf just visible and watery grain ripe phenological stages (37-71 BBCH scale) is pivotal. In terms of resource efficiency and with a precision farming perspective, it is essential to develop ways of monitoring plant nutritional status, to have reliable decision support tools during advanced crop development stages. Indices based on crops spectral characteristics or leaf-clip sensors, have been widely investigated by researchers. Moreover, such tools, in which photosynthetic pigments content are used as an indicator of leaf N content, are nowadays commercially available. Besides costs, the limitation of proximal instruments lies in the requirement of multiple measurements to obtain a reliable picture of the state of the entire field. Unmanned Aerial Vehicle (UAV)-mounted multi-hyperspectral sensors can solve this problem, but they require the use of expensive equipment and specialized knowledge for data analysis. The aim of this study was to evaluate whether Red Green Blue (RGB)-based indices, such as the Green Leaf Index (GLI) and Dark Green Colour Index (DGCI) can effectively assess the presence of N deficiencies in wheat at advanced development stages, providing comparable information to those obtained from widely known indices, such as Normalized Difference Vegetation Index (NDVI) and Nitrogen Balance Index (NBI). A fertilization trial was performed on common wheat (var. 'Bologna') testing four nitrogen x sulphur fertilization strategies in comparison with an unfertilized control. Each fertilization strategy was replicated 3 times in containers of 100-L volume (0.25-m² area and 0.4-m height). Starting from flag leaf opening (BBCH 47), weekly measurements were carried out. NDVI was obtained using a handheld crop sensor (GreenSeeker Model, HSC-100, Trimble, Sunnivale, USA), while NBI was obtained using leaf-clip sensor (DualEx®, Force-A, Orsay, FR). Aerial images were obtained using a Mavic Mini quadcopter UAV (DJI, Shenzhen, China), and analysed using GIMP software (version 2.10.36). A total of four flights were carried out. Subsequently, a correlation analysis was performed among the obtained indices using R software (version 4.2.3). Both DGCI and GLI

showed a statistically significant correlation with proximal sensing indices. However, the strongest correlation ($r = 0.84$) was observed between DGCI and NDVI. On the contrary, GLI showed weaker correlations with all the assessed indices. In accordance with these results, DGCI can provide comparable information to that obtained from multispectral or leaf-clipper sensors, during late wheat development stages. The use of such low-cost tools can be carried out directly by the farmer, promoting the spread of precision farming practices. However, further studies will be necessary in order to confirm these preliminary findings, considering different cultivation and environmental conditions, including plot-scale or field-scale trials.