World Academy of Science, Engineering and Technology
International Journal of Agricultural and Biosystems Engineering
Vol:19, No:11, 2025

Classification of Foliar Nitrogen in Common Bean (Phaseolus Vulgaris L.) Using Deep Learning Models and Images

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Abstract : Common beans are a widely cultivated and consumed legume globally, serving as a staple food for humans, especially in developing countries, due to their nutritional characteristics. Nitrogen (N) is the most limiting nutrient for productivity, and foliar analysis is crucial to ensure balanced nitrogen fertilization. Excessive N applications can cause, either isolated or cumulatively, soil and water contamination, plant toxicity, and increase their susceptibility to diseases and pests. However, the quantification of N using conventional methods is time-consuming and costly, demanding new technologies to optimize the adequate supply of N to plants. Thus, it becomes necessary to establish constant monitoring of the foliar content of this macronutrient in plants, mainly at the V4 stage, aiming at precision management of nitrogen fertilization. In this work, the objective was to evaluate the performance of a deep learning model, Resnet-50, in the classification of foliar nitrogen in common beans using RGB images. The BRS Estilo cultivar was sown in a greenhouse in a completely randomized design with four nitrogen doses (T1 = 0 kg N ha-1, T2 = 25 kg N ha-1, T3 = 75 kg N ha-1, and T4 = 100 kg N ha-1) and 12 replications. Pots with 5L capacity were used with a substrate composed of 43% soil (Neossolo Quartzarênico), 28.5% crushed sugarcane bagasse, and 28.5% cured bovine manure. The water supply of the plants was done with 5mm of water per day. The application of urea (45% N) and the acquisition of images occurred 14 and 32 days after sowing, respectively. A code developed in Matlab© R2022b was used to cut the original images into smaller blocks, originating an image bank composed of 4 folders representing the four classes and labeled as T1, T2, T3, and T4, each containing 500 images of 224x224 pixels obtained from plants cultivated under different N doses. The Matlab© R2022b software was used for the implementation and performance analysis of the model. The evaluation of the efficiency was done by a set of metrics, including accuracy (AC), F1-score (F1), specificity (SP), area under the curve (AUC), and precision (P). The ResNet-50 showed high performance in the classification of foliar N levels in common beans, with AC values of 85.6%. The F1 for classes T1, T2, T3, and T4 was 76, 72, 74, and 77%, respectively. This study revealed that the use of RGB images combined with deep learning can be a promising alternative to slow laboratory analyses, capable of optimizing the estimation of foliar N. This can allow rapid intervention by the producer to achieve higher productivity and less fertilizer waste. Future approaches are encouraged to develop mobile devices capable of handling images using deep learning for the classification of the nutritional status of plants in situ.

Keywords : convolutional neural network, residual network 50, nutritional status, artificial intelligence
Conference Title : ICAACS 2025 : International Conference on Agriculture, Agronomy and Crop Sciences
Conference Location : Las Vegas, United States
Conference Dates : November 15-16, 2025