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PREDICTION OF MASS PRODUCTION OF FABA BEAN CROP USING DIGITAL IMAGE ANALYSIS

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Abstract

Accurate estimation of crop biomass is essential for assessing crop growth, yield potential, and optimizing agricultural management practices. Digital image analysis has emerged as a promising tool for non-destructive and efficient biomass prediction in crop production. In this study examine the predictive capabilities of digital image analysis for faba bean biomass estimation. Utilizing RGB (Red, Green, Blue) and vegetation indices image analysis techniques, the digital images was analyses of faba bean plant in fields to extract relevant biomass characteristics and quantify biomass. Through computational modelling and simulation, it assess the accuracy and reliability of these models across 100 days of growth and environmental conditions. The test analysis were conducted in the laboratory of the Agricultural Engineering Department. The results showed varying with the green biomass with the color indicators used, through which the green mass can be predicted. A linear equation appears relationship between normalized difference index and mass production during days of faba bean growth it was $y = 6.0166x + 215.85$ *with* $R^2 = 0.9495$ *.*

Key words: *prediction, modelling, biomass, digital image*

INTRODUCTION

Faba bean, a significant member of the legume family, stands out for its high protein content and promising developmental prospects. Seeds have special physical properties closely connected with their quality and yield [1, 6].
Yield is an important phenotypic trait of crops, and early yield estimates can inform field management decisions. To quickly and accurately estimate faba bean yield, this study collected and analyzed dual-sensor data (RGB and multispectral) acquired using an unmanned aerial vehicle (UAV). This study explores the potential of integrating RGB and multispectral sensor data as well as data from different growth stages to build a faba bean yield estimation model. Additionally, the impact of different machine learning algorithms and plant species on the accuracy of these models was examined [3], [4]. Yield, a significant phenotypic trait representing the ultimate goal of crop breeding, has spurred the emergence of spectroscopy as a crucial technology. Spectroscopy, which involves generating spectra from diverse substances and their interactions, has been adapted by agricultural researchers into a discipline known as agricultural spectroscopy. This discipline quantifies phenotypic traits by analyzing interactions between plant traits and spectra [5]. The application of digital image analysis techniques in predicting faba bean biomass is pivotal for evaluating crop growth and estimating yield potential, alongside refining crop management practices. This review delves into diverse methodologies and strategies employed in digital image analysis for biomass prediction, encompassing image segmentation, feature extraction, and machine learning algorithms. Furthermore, it explores the benefits, hurdles, and potential advancements associated with the integration of digital image analysis in predicting faba bean biomass [11]. Estimating aboveground biomass (AGB) accurately and quickly is essential for monitoring crop growth status and predicting grain yield. It serves as a vital indicator for assessing crop nutrition status and refining crop management strategies [12].
Faba bean (*Viciafaba*) stands as a crucial leguminous crop, boasting substantial economic and nutritional significance. The precise anticipation of faba bean biomass holds paramount importance in refining crop management techniques, gauging yield

potential, and ensuring crop health monitoring. The advent of digital image analysis presents a promising avenue for non-invasive and effective biomass estimation in faba bean cultivation. This review presents a comprehensive exploration of ongoing research endeavours focused on predicting faba bean biomass through the utilization of digital image analysis technique [14].

Accurate assessment of crop biomass holds paramount importance in evaluating crop growth, potential yield, and enhancing agricultural management strategies. The emergence of digital image analysis presents a promising avenue for non-invasive and effective biomass prediction in crop cultivation. This review delves into the present research landscape surrounding the prediction of crop biomass through the utilization of digital image analysis techniques. It investigates various methodologies, hurdles, and future opportunities within this domain [15]. The utilization of RGB (Red, Green, Blue) image analysis techniques in forecasting crop biomass, a pivotal factor in evaluating crop growth and yield potential, is explored in this review. RGB image analysis provides a non-invasive and effective means of estimating biomass by harnessing color data from digital images of crop fields. The review investigates diverse methodologies, encompassing color segmentation, feature extraction, and machine learning algorithms, applied in the prediction of crop biomass using RGB image analysis [16]. Leaf-area index (LAI) and biomass are critical parameters in understanding ecosystem dynamics and biogeochemical processes. LAI represents the amount of leaf surface area relative to the ground area, providing insights into vegetation structure, productivity, and energy exchange. Biomass, on the other hand, quantifies the total mass of living vegetation per unit area, indicating the amount of organic matter produced by plants [13].

The reflected light is analyzed by vegetation indices to detect plants and assess their status. The healthy plants were riched in chlorophyll and reflect near-infrared and more green light than those with stressed or dead leaves.

Vegetation indices, such as the Normalized Difference Vegetation Index (NDVI) or Enhanced Vegetation Index (EVI), quantify these spectral characteristics to provide valuable insights into plant health, biomass, and productivity. By measuring the ratio of reflected light in specific spectral bands, these indices can distinguish between healthy and stressed vegetation, aiding in early detection of plant diseases, nutrient deficiencies, or environmental stressors [17].

The aim of this study was to predict biomass of a single plant correlate with color indices based on RGB bands during faba bean growth period.

MATERIALS AND METHODS

Simulation models was constructed by C^{++} to predict of faba bean biomass during growth faba bean crop (10, 30, 55, 80, and 100 days) as shown in Photo 1, the color vegetation indices from planting to end to reflecting production of faba bean crop.

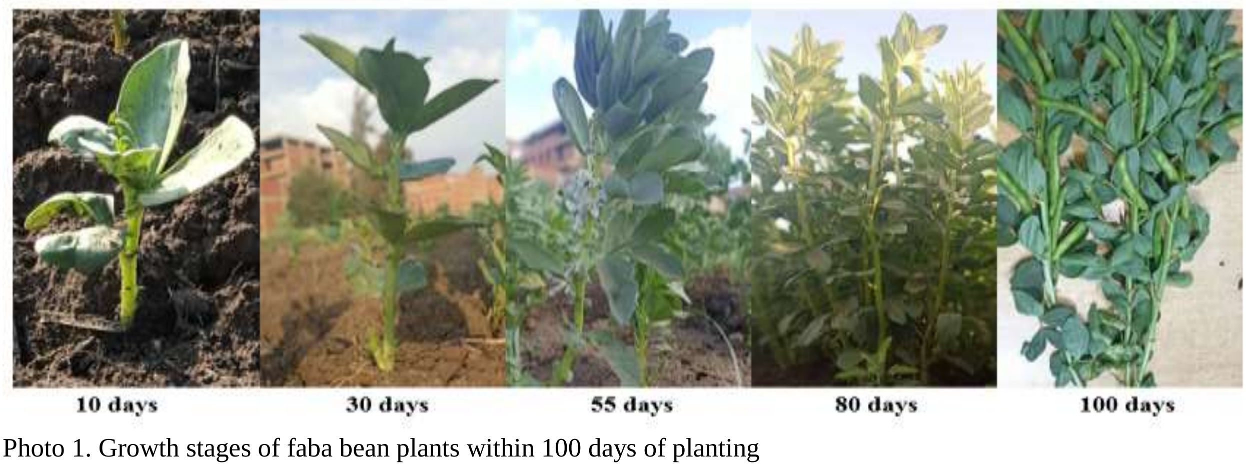

Photo 1. Growth stages of faba bean plants within 100 days of planting
Source: Author's' determination.

Image Processing technique and RGB bands

750 photo was taken during the plant's life and MATLAB software was used to extract the Red, Green, and Blue bands from an image of faba bean plant, Photo 2 showed the sequence to extract the image and RGB bands

Vegetation indices and biomass of faba bean crop

The relationship between vegetation indices and the increase in biomass of plants can vary depending on several factors, including the specific index used, the stage of plant growth, and environmental conditions.

However, a positive correlation between vegetation indices and biomass increase:

1-Greenness Indices (GR, GRVI, VEG, GLI, ExG, RGBVI, MGRVI, VARI):

These indices typically measure the amount of green vegetation present.

As biomass increases, there is usually more green foliage, leading to higher values of these indices.

2-*Redness Indices* (ExR, NDI, CIVE, ExGR, COM1, COM2):

These indices assess variations in red reflectance, which can be related to changes in biomass density, especially in mature or senescent plants.

Higher biomass may lead to alterations in red reflectance due to changes in leaf structure or pigment content

3-Blue-Green Indices (BGI2, NGBDI, GB):

Blue-green indices measure the relationship between blue and green reflectance, which can be influenced by factors such as leaf area and chlorophyll content.

An increase in biomass may lead to changes in these indices due to variations in leaf density and chlorophyll concentration.

4- Combined Indices (RGBVI2, RGBVI3, Hue, Intensity)

These indices consider multiple bands or color spaces, capturing additional information about vegetation characteristics.

Changes in these indices with increasing biomass may reflect alterations in plant structure

Flowchart presented in Photo 3 showed the calculation of color vegetation indices based RGB bands.

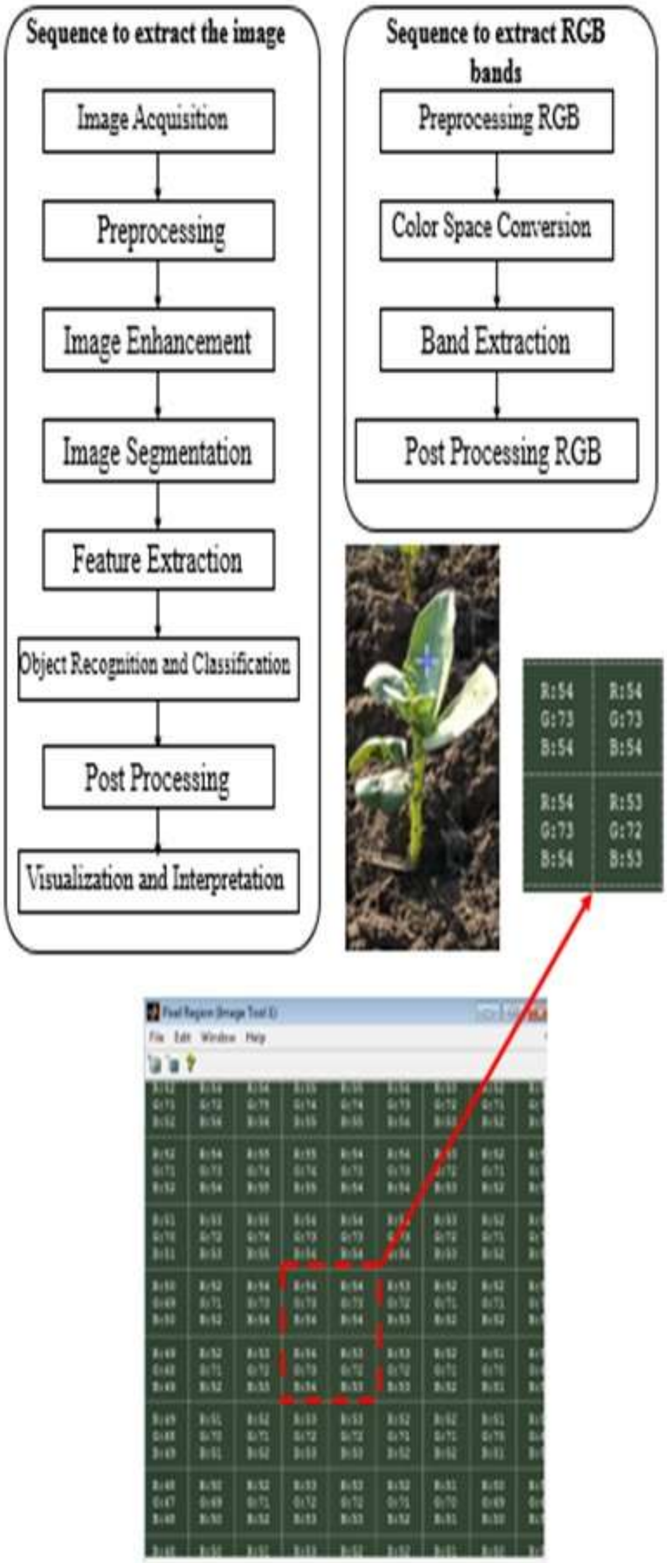

Photo (2): Flowchart showing the sequence to image and RGB bands in Matlab software
Source: Author's prepared.

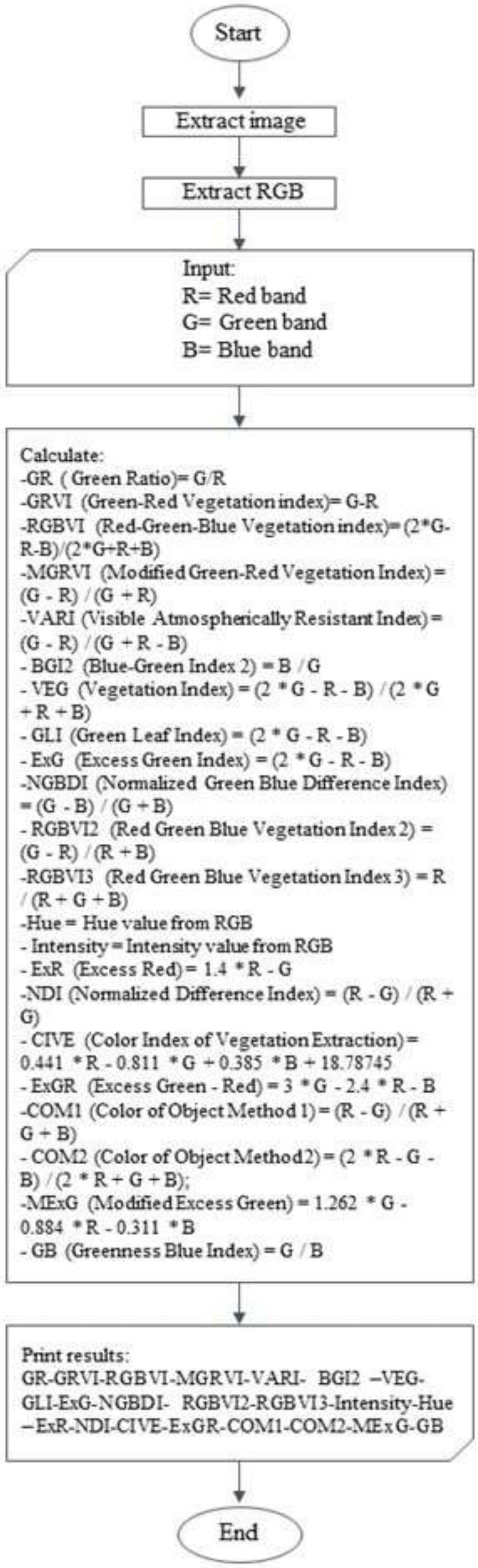

Photo (3): Flowchart showing the sequence to estimate the color vegetation indices
Source: Author's prepared
Source: [1], [3], [5], [6], [7], and [8].

RESULTS AND DISCUSSIONS

The most vegetation indices increased for mass production and green pods.

Figure 1 showed the maximum values of simple red–green ratio, green leaf, visible atmospherically resistant index, normalized green-blue difference index, and simple blue–green ratio recorded to 0.265, 0.781, 1.239, 0.811, and 0.366, with the mass production value was 508.75 g.

Figure 2 showed when mass production increased from 7.67 to 508.75 g. the intensity increased from 61.66 to 85.35. Also the same trend showing in the excess green minus excess red index, increased from 52.00to 91.00, green band from150,to 205, normalized difference index from 223.481, to 245.331, green minus blue from 113 to 172, excess red indexfrom146 to 300, and modified excess green indexfrom178.238,to 231.431.

Figure 3 showed the maximum values of RGB-based vegetation index, modified green–red vegetation index and combination of green indices 2 gives slightly increased in difference values with mass production of faba bean crop while with colour index of vegetation extraction and combination of green indices 1 it gives a clear increase in the difference values with mass production.

Figure 4 showed the maximum values of Hue Gives slightly increased in difference values with mass production of faba bean crop while with RGB-based vegetation index 2, and 3) it gives a clear increase in the difference values with mass production.

Figures 5 and 6 showed the linear regression analysis run to derive equations to predict the relationship between normalized difference index and mass production during of faba bean growth. The following equation represented the relationship.

$$y = 6.0166x + 215.85 \quad R^2 = 0.9495$$

Also, the relationship between the colour index of colour Index of vegetation extraction and mass production during faba bean growth is represented by the following equation.

$$y = 20717x + 78293 \quad R^2 = 0.9448$$

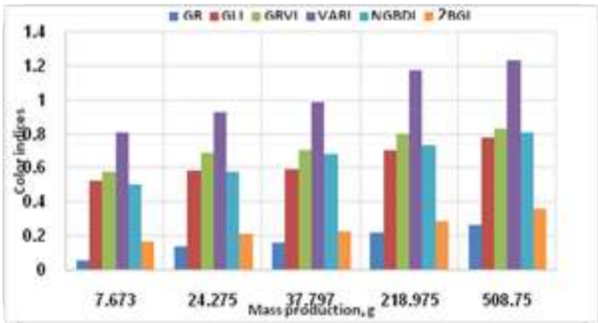

Fig. 1. Relationship between color indices and mass production of faba bean crop
Source: Authors' determination.

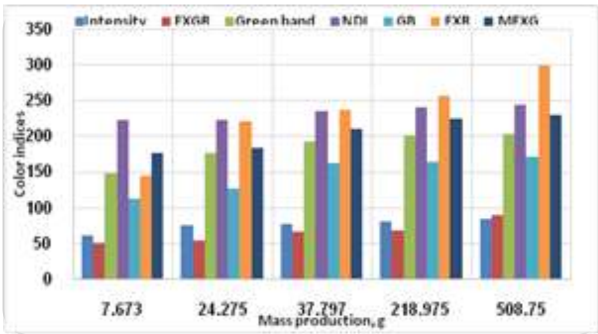

Fig. 2.. Relationship between color indices and mass production of faba bean crop
Source: Authors' determination.

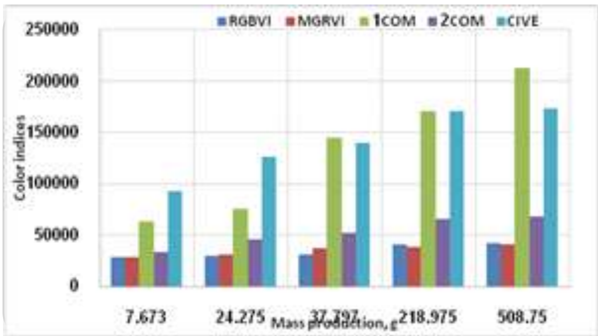

Fig. 3. Relationship between color indices and mass production of faba bean crop
Source: Authors' determination.

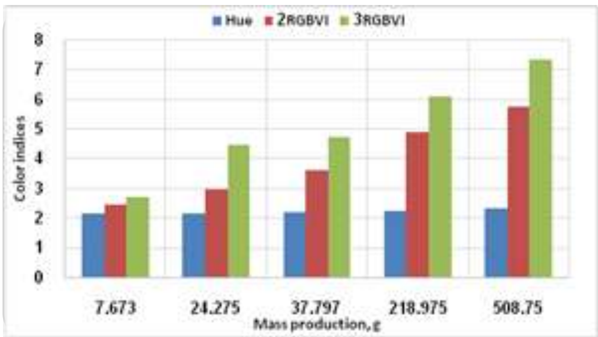

Fig. 4. Relationship between color indices and mass production of faba bean crop
Source: Authors' determination.

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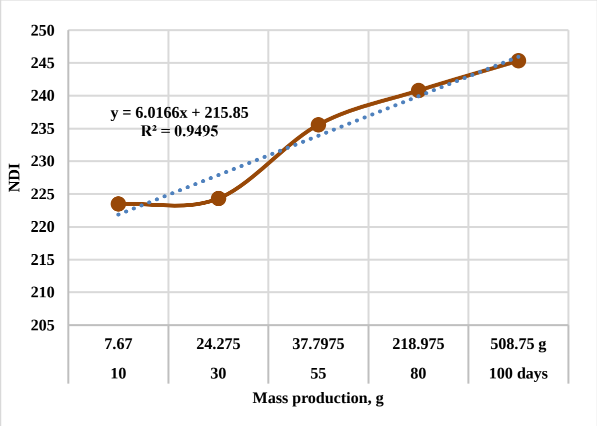

Fig. 5. Relationship between normalized difference index and mass production during of faba bean growth
Source: Authors' determination.

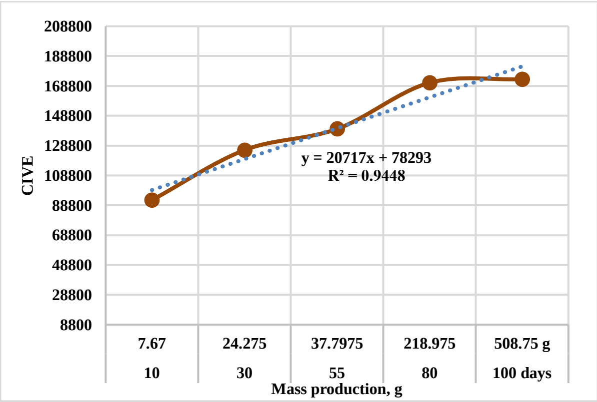

Fig. 6. Relationship colour index of colour Index of vegetation extraction and mass production during faba bean growth
Source: Authors' determination.

Table 1. The color indices values of mass production and green pods of faba bean crop

Vegetation indices	mass production
	8-100 days
GR	16%
GRVI	3%
RGBVI	3%
MGRVI	6%
VARI	5%
BGI2	20%
VEG	61%
GLI	10%
ExG	21%
NGBDI	9%
RGBVI2	15%
RGBVI3	17%
Hue	4%
Intensity	4%
ExR	14%
NDI	2%
CIVE	11%
ExGR	24%
COM1	19%
COM2	4%
MExG	2%
GB	4%
GR	16%
Green band	1%

Source: Authors' determination.

Table 1 shows the differences of color indices values with mass production of faba bean crop. When mass production increased from 7.67 to 508.75 g. the color indices values increased by 16,19 and 24% with GR , COM1 and ExGR.

CONCLUSIONS

The research results demonstrate the effectiveness of color indices which extracted from RGB images for estimating biomass of faba bean crop during growth period. Additionally, the utilization of image processing techniques and extraction of vegetation indices from these images. The values of color vegetation indices were measured during 100 days.

REFERENCES

[1]Abdelsalam, A., Fouda, T. 2023, Determination of color properties of some seeds. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 23(1), 15-20.

[2]Bendig, J., Yu, K., Aasen, H., Bolten, A., Bennertz, S., Broscheit, J., Gnyp, M.L., Bareth, G., 2015, Combining UAV-based plant height from crop surface models, visible, and near infrared vegetation indices for biomass monitoring in barley. International Journal of Applied Earth Observation and Geoinformation, 39, 79-87. Accessed on 27 April 2024.

[3]Cui, Y., Ji, Y., Liu, R., Li, W., Liu, Y., Liu, Z., Zong, X., Yang, T., 2023, Faba Bean (*Viciafaba* L.) Yield Estimation Based on Dual-Sensor Data. Drones 2023, 7, 378. Accessed on 27 April 2024.

[4]Du, Z., Zhang, X., Xu, X., Zhang, H., Wu, Z., Pang, J., 2017, Quantifying influences of physiographic factors on temperate dryland vegetation, Northwest China. Scientific reports, 7(1), 40092. Accessed on 27 April 2024.

[5]Farvid, M. S., Sidahmed, E., Spence, N. D., Mante Angua, K., Rosner, B. A., Barnett, J. B., 2021, Consumption of red meat and processed meat and cancer incidence: a systematic review and meta-analysis of prospective studies. European journal of epidemiology, 36, 937-951.Accessed on 27/4/2024.

[6]Fouda, T., Abdelsalam, A., Swilam, A., Didamony, M.E.,2022, determination of physical properties of some seeds. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 22(3), 223-238.

[7]Gamon, J. A., Surfus, J. S., 1999, Assessing leaf pigment content and activity with a reflectometer. The New Phytologist, 143(1), 105-117. Accessed on 27 April 2024.

[8]Gitelson, A. A., Kaufman, Y. J., Stark, R., Rundquist, D., 2002, Novel algorithms for remote estimation of

vegetation fraction. Remote sensing of Environment, 80(1), 76-87. Accessed on 27 April 2024.

[9]Hague, T., Tillett, N. D., Wheeler, H., 2006, Automated crop and weed monitoring in widely spaced cereals. Precision Agriculture, 7, 21-32. Accessed on 27 April 2024. https:// doi.org/10.3390/drones7060378

[10]Khojastehnazhand, M., Omid, M., Tabatabaeefar, A., 2009, Determination of orange volume and surface area using image processing technique. International Agrophysics, 23(3), 237-242. Accessed on 27 April 2024.

[11]Li, C., Zhang, Q., Huang, D., 2020, Review on Digital Image Processing in Agriculture. IOP Conference Series: Earth and Environmental Science, 522(1), 012003. Accessed on 27 April 2024.

[12]Lu, N., Zhou, J., Han, Z., Li, D., Cao, Q., Yao, X., Tian, Y., Zhu, Y., Cao, W., Cheng, T., 2019, Improved estimation of aboveground biomass in wheat from RGB imagery and point cloud data acquired with a low-cost unmanned aerial vehicle system. Plant Methods, 15, 1-16.Accessed on 27 April 2024.

[13]Räsänen, A., Juutinen, S., Kalacska, M., Aurela, M., Heikkinen, P., Mäenpää, K., Rimali, A., Virtanen, T., 2020, Peatland leaf-area index and biomass estimation with ultra-high resolution remote sensing. GIScience& Remote Sensing, 57(7), 943-964. Accessed on 27 April 2024.

[14]Sankaran, S., Khot, L. R., Espinoza, C. Z., Jarolmasjed, S., Sathuvalli, V. R., Vandemark, G. J., Miklas, P. N., 2015, Low-altitude, high-resolution aerial imaging systems for row and field crop phenotyping: A review. European Journal of Agronomy, 70, 112-123.Accessed on 27 April 2024.

[15]Saravia, D., Valqui-Valqui, L., Salazar, W., Quille-Mamani, J., Barboza, E., Porras-Jorge, R., Injante, P., Arbizu, C. I., 2023, Yield prediction of four bean (*Phaseolus vulgaris*) cultivars using vegetation indices based on multispectral images from UAV in an arid zone of Peru. Drones, 7(5), 325. Accessed on 27 April 2024.

[16]Sharma, S., Singh, R., Sharma, A., 2017, Application of RGB Image Analysis in Predicting Crop Biomass: A Review. International Journal of Agricultural Sciences, 9(2), 87-96. Accessed on 27 April 2024.

[17]Smith, A. B., Jones, C. D., 2020, Predicting Crop Biomass Using Digital Image Analysis. Journal of Agricultural Science, 10(3), 123-135. Accessed on 27 April 2024.