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INTEGRATING IMAGE PROCESSING TECHNIQUES WITH VEGETATION INDICES FOR MONITORING GROWTH STAGES AND GENERAL HEALTH FOR FABA BEAN CROP

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Abstract

The measurable value of vegetation cover resulting from image RGB bands was used in monitoring the growth stages of faba bean crop as well as obtaining information about the accuracy of vegetation analysis. In addition, this process takes little time while field measurements give results on small spatial scales with high temporal data. Usually requires a lot of measuring and sampling. In addition, this process takes a long time. The highest accuracy and the shortest time to extract color characteristics, it was advised to utilize an assistant programming program Matlab with using digital picture to verify the color vegetation indices during growth periods of faba bean crop from November 2021 to February 2022. The results showed an increase in the percentage values of green band, intensity, Hue, EXGR, GVI, VARI, NDI, EXG, VEG, CIVE, and MEXG through (budding, to podding) stages were 4.65, 7.13, 24.54, 24.12, 28, 11.24, 15.11, 83.66, 60.79, and 15 % respectively. RGB Vegetation Indices which used accurately to distinguish and monitor the condition of the plant GRVI (Green Red Vegetation Index) VARI (Visible Atmospheric Resistance Index) GLI (Green Leaf Index) TGI (Triangular Greenness Index)To describe of crop health and growth rates

Key words: *faba bean,vegetation indices, RGB bands, monitoring*

INTRODUCTION

Grain legume crops like faba beans play essential roles within the farming system. Faba beans, both large and small-seeded varieties, are considered the most significant grain legumes. They serve as a vital source of nutrition for both humans and animals alike [2].

The faba bean stands out as the foremost food legume crop globally and serves as the primary cool-season food and feed legume in numerous countries. Its adaptability to diverse soil types and environmental conditions further enhances its significance. With over 4.1 million households cultivating this crop across nearly 0.5 million hectares of land, it yields a remarkable one million tonnes of grain [3].

In recent years, there has been a rising interest in enriching food products through the inclusion of plant proteins in their formulations. Faba bean, boasting a protein content of around 29% and a well-balanced amino acid profile, holds promise as an excellent source of plant-derived protein [16]

In 2024, digital image analysis (DIA) has become an indispensable tool in modern agriculture, revolutionizing the way farmers and agronomists monitor, manage, and optimize crop production. By leveraging advancements in technology and machine learning algorithms, DIA enables the extraction of valuable insights from high-resolution satellite imagery, aerial drone footage, and ground-based sensors. These insights encompass a wide range of agricultural applications, including crop monitoring, disease detection, yield prediction, soil health assessment, and precision farming. DIA empowers farmers to make data-driven decisions at every stage of the growing season, from field planning and planting to irrigation and harvesting. Through the analysis of spectral indices, such as NDVI (Normalized Difference Vegetation Index) and NDRE (Normalized Difference Red Edge), DIA provides real-time information on crop health and vigour, allowing for timely interventions to optimize inputs, reducing costs, and maximizing yields [15].

The average of faba bean for the Red color band was 133.63, in Blue color band was 43.68, and in Green color band was 97,94 while Hue was 0. 626.Also the intensity and the browning index was 91.75, 16.25 respectively [1].

Precision Agriculture, also known as Smart Farming, seeks to enhance crop yield, minimize production expenses, and mitigate environmental repercussions. Within this realm, a prominent research focus centres on automating the identification of crops in digital imagery to facilitate plant classification, growth monitoring, and the detection of issues like water stress, nutrient deficiencies, or plant health concerns. This endeavour is particularly challenging in open-field cultivation settings, where factors such as varying natural lighting, weather conditions, and diverse agricultural practices adopted by farmers complicate the task [8].

Image-based RGB bands employ image processing and machine learning techniques to derive quantitative measurements of plants' structural and functional characteristics. This method enables the monitoring of plant growth, health, and physical attributes directly from images, offering a quicker and more precise evaluation of field areas [14].

Image processing involves converting RGB color units to Lab* values (segment labelling) required for graphics and analysis purposes. This conversion from the RGB color space to the CIE Lab color space is achieved in two steps. The initial step entails the RGB to XYZ transformation, followed by the second step which involves the XYZ to Lab* transformation [7].

The analysis of strawberry fruit images, along with their chemical properties, was conducted using the ENVI software package. Various applications of gibberellic acid and citrate potassium were explored. Chemical properties such as total soluble solids and anthocyanin content were assessed under different treatment conditions and correlated with image indices. RGB values (red, green, blue) were derived from each image, leading to the determination of color indices including the Red/Green ratio (R/G), hue, and intensity (I). The findings revealed significant correlations between certain chemical parameters and color indicators [6].

Utilizing color indices offers the advantage of enhancing specific color of interest, thereby emphasizing certain visual attributes. In the images under analysis, the predominant spectral signature is typically green, representing plant foliage. Consequently, for the purpose of accentuating greenness, indices such as ExG, CIVE, ExGR, VEG, NDI, and ExR were chosen due to their observed effectiveness in yielding favourable results [12].

Nowadays, techniques for extracting data from images are gaining traction due to their simplicity, cost-effectiveness, and speed. These methods often involve the utilization of software programs such as Matlab for analysing plant images [21].

The objective of this study was to possibility of integrating image processing techniques with vegetation indicators to monitor the faba bean crop during growth periods and determine the vegetation indices with RGB bands of faba bean crop growth starting from agriculture to harvesting and describe of crop health and growth rates.

MATERIALS AND METHODS

A field experiment was conducted to grow faba bean in November 2021 to February 2022 (5-27/11/2021 budding, 2-26/12/2021 branching,3-23/1/2022 flowering, and 26/1/2022 to 22/2/2022 podding) to verify the color vegetation indices from planting to end.The experiments field located between 30°48'15.9"N 30°58'56.2"E as shown in Photo 1.

Photo 1. The experiments field (Faba bean crop)
Source: Author's' determination.

Image Processing Techniques

MATLAB software was used to determine the three additive primary colours of faba bean plant, referred to as RGB. The 'R' value indicates the red band; the 'G' value represents the green band; and the 'B' value represents the blue band.

Xiaomi Redmi Note 10 Camera

The picture was taken by mobile "Xiaomi Redmi Note 10 Camera" to get RGB bands, the main and the ultra-wide are pretty much the standard too - 48MP main unit with f/1.8 aperture. The sensor itself is 1/2.0" big and offers 0.8μm pixels and, outputs 12MP images by combining four adjacent pixels into one.

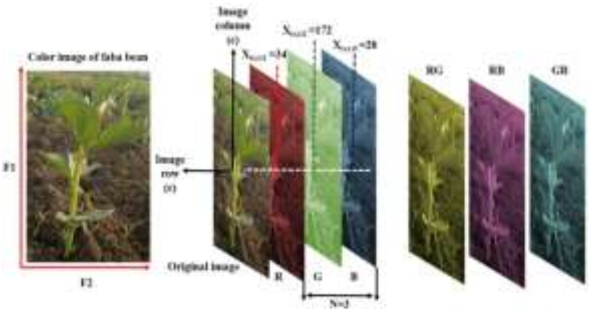


Photo 2. Color image interpretation in the RGB color domain
Source: Author's determination.

As for the ultra-wide, it's the popular 8MP, 1/2.0", 1.12μm pixels sensor paired with f/2.2 aperture that everyone uses. This particular implementation promises a 118-degree field of view (Photo 2).

Acquisition and Processing of RGB-Based Data

The RGB images were pre-processed in MATLAB software, and the steps included picture calibration, picture cropping, background removal, plant area selection, field canopy coverage extraction as shown in Photo 3. The R, G, and B channels of an image are determined by its design. They are characterized by their spectrum sensitivities, giving the distinct wavelengths, the greatest values of the spectral sensitivities for the red, green, and blue bands of the picture were 163, 235, and 153 with wavelength ranges between 350 and 400 nm. Also, the minimum values of same indices were 118, 143, and 58 with wavelength ranges between 80 and 100 nm respectively.

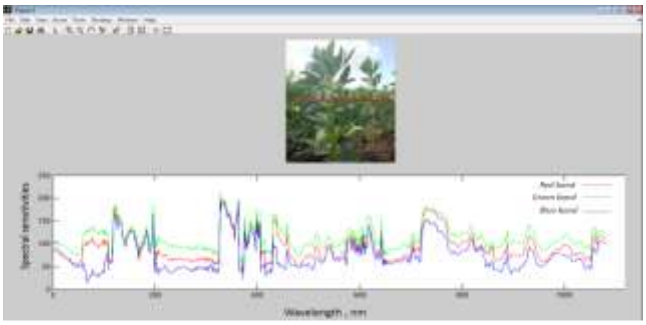


Photo 3. Relationship between spectral sensitivities and wavelength of faba bean crop
Source: Author's ' determination.

Vegetation Indices

RGB vegetation index were summarized in Table 1.

Table 1. The RGB vegetation index were using in assessing the crop's growth stage and general crop health

Acronym	Indices	Formula	Author and year
GR	Simple red–green ratio	$\frac{R}{G}$	Gamon et al 1999 [9]
GRVI	Green–red vegetation index	$\frac{G-R}{G+R}$	Tucker et al 1979 [17]
RGBVI	RGB-based vegetation index	$\frac{G^2-(BXR)}{G^2+(BXR)}$	Bendig et al 2015 [4]
MGRVI	Modified green–red vegetation index	$\frac{G^2-R^2}{G^2+R^2}$	Bendig et al 2015 [4]
VARI	Visible atmospherically resistant index	$\frac{G-R}{G+R-B}$	Gitelson et al 2002 [10]
BGI2	Simple blue–green ratio	$\frac{B}{G}$	Zarco-Tejada et al 2005 [20]
VEG	Vegetative	$\frac{G}{R^2XB^{(1-a)}}\ ; a = 0.667$	Hague et al 2006 [11]
GLI	Green leaf	$\frac{2G-R-B}{2G+R+B}$	Woebbecke et al 1995[18]
ExG	Excess green index	2G-R-B	Du et al 2017 [5]
NGBDI	Normalized green-blue difference index	$\frac{G-B}{G+B}$	Du et al 2017[5]
RGBVI2	RGB-based vegetation index 2	$\frac{G-R}{B}$	Proposed
RGBVI3	RGB-based vegetation index 3	$\frac{G+B}{R}$	Proposed
Hue	Hue	$COS^{-1}(\frac{(2R-G-B)/2}{(R-G)^2+(R-B)(COSG-B)^{0.5}})$	Khojastehnazhand et al., 2009[13]

I	Intensity	$\frac{1}{3}(R+G+B)$	
I_2	Intensity	(R-B)/2	
ExR	Excess Red Index	2∗G − R – B	Du et al 2017 [5]
NDI	Normalized Difference Index	128 ∗ ((G − R)/(G + R)) + 1	Du et al 2017 [5]
CIVE	Colour Index of Vegetation Extraction	0.441∗R − 0.811∗G + 0.385∗B + 18.78745	Hague et al 2006 [11]
ExGR	Excess Green Minus Excess Red Index	ExG – ExR	Du et al 2017 [5]
COM1	Combination of green indices	ExG + CIVE + ExGR + VEG	Bendig et al 2015 [4]
COM2		0.36∗ExG + 0.47∗CIVE + 0.17∗VEG	Bendig et al 2015 [4]
MExG	Modified Excess Green Index	1.262∗G − 0.884∗R − 0.311∗B	Bendig et al 2015[4]
GB	Green minus Blue	G-B	Bendig et al 2015[4]

Source: Author's synthesis.

RESULTS AND DISCUSSIONS

The most vegetation indices increased , during the first, second, third, and fourth stages of growth periods. From Fig. 1 to Fig (5) and Table 2.

The results showed Intensity increased to (79.13, 80.13, 82.2, and 83) related to the color's overall brightness. Also EXGR increased to point out positive ExGR values suggest areas with more green than red, To estimate plant health and biomass point to VARI, GR indicesthe Simple Red-Green Ratio and Green–Red Vegetation Index is a fundamental vegetation metric., Green band expressed in excess to (0.06, 0.12, 0.14, and 0.2) during the first, second, third, and fourth stages The green band measurement provides valuable information about the characteristics of vegetation, as chlorophyll, the pigment responsible for photosynthesis in plants, strongly absorbs red and blue light while reflecting green light, Hue increased to (2.1, 2.22, 2.24, and 2.26) during the first, second, third, and fourth stages the "Hue" component refers to the characteristic of colour that separates one colour from another, such as red, green, blue, GRVI It increases (0.66, 0.74, 0.77, and 0.87) during the first, second, third, and fourth stages used to estimate plant health and biomass.

BGI2 in excess to (0.21, 0.23, 0.24, and 0.28) during the first, second, third, and fourth stages it reflects of plant vigor and density because healthy vegetation absorbs more blue light for photosynthesis while reflecting more green light owing to chlorophyll content. Also GLI It stands out more to (0.64, 0.65, 0.68, and 0.73) to analyze the chlorophyll concentration and health of green plants. It is very useful for assessing crop health and vigor. The signal from RGBVI2 was increased to (3.14, 3.88, 4.26, and 4.54) during the first, second, third, and fourth stages it focuses on the contrast between green and red reflectance, which can be indicative of vegetation presence. Also RGBVI3 indicator shows an increase (4.2, 5, 5.15, and 6.49) It captures the contrast between red and non-red features in RGB imagery, which can be useful for identifying vegetation against backgrounds with low red reflectance, EXG (264.5, 276.9, 297, and 311.6) during the first, second, third, and fourth stages it measures the quantity of green in a picture relative to red and blue. Also ExG emphasizes the distinction between green and non-green components in a picture,. NDI indicator shows a clear increase to (212.7, 223.4, 227.4, and 239.6) during the first, second, third, and fourth stages it Determines the normalized difference between the red and green band, which aids in enhancing certain aspects or qualities of interest in the images

NGBDI indicator that shows a steady increase to (0.55, 0.61, 0.63, and 0.66) during the first, second, third, and fourth stages it measures the relative difference between green and blue reflectance. Higher NGBDI values indicate areas with higher green reflectance than blue reflectance,

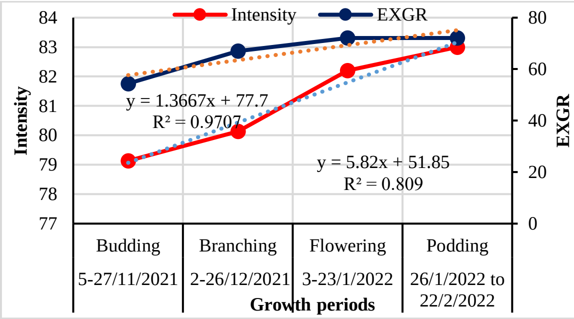
VEG indicator of an increase to (0.58, 1.02, 1.27, and 3.55) uses RGB bands to quantify several aspects of plant cover and health, Also COM1 and COM2 indicators of a high range increase and both indices were beginning points for determining greenness, GB increased to (120.7, 137.8, 138, and 140.8) during the first, second, third, and fourth stages used in image processing to evaluate plant properties based on the reflectance difference between green and blue spectral bands, CIVE increases the contrast between vegetation and non-vegetation regions by emphasizing the green color of the vegetation. It accomplishes this by eliminating the red component and adding the blue component, EXR An indicator of a high range increase to (192.4, 204.8, 230, and 257.2) during the first, second, third, and fourth stages Higher values imply a greater proportion of red pixels compared to green and blue pixels, which are often associated with vegetation, and MEXG 175.9, 177.5, 195.7, and 207) during the first, second, third, and fourth stages it computes the difference between green reflectance and the mean of red and blue reflectance. By removing the average of red and blue from green. From Fig. 6 to Fig. 12 whereas the highest values were in February 2022, and the lowest values were in November 2021 for the previous indices.

In Table 2 showed Percentage of increase and decrease of RGB vegetation index value during faba bean growth stage during growth periods of faba bean crop during November 2021 to February 2022.

The results showed an increase in the percentage values of green band, intensity, Hue, EXGR, GVI, VARI, NDI, EXG, VEG, CIVE, and MEXG through (budding, to podding) stages were 4.65, 7.13, 24.54, 24.12, 28, 11.24, 15.11, 83.66, 60.79, and 15 % respectively.

Some of RGB Vegetation Indices which used accurately to distinguish and monitor the condition of the plant GRVI (Green Red Vegetation Index)VARI (Visible Atmospheric Resistance Index) GLI (Green Leaf Index) TGI (Triangular Greenness Index) To describe and give an indicator of crop health and growth rates.

In Table 3 showed the linear regression equations was performed to predict the RGB vegetation index were using in assessing the crop's growth stage and general crop health.



FFig. 1. Relationship between intensity and excess green minus excess red index during growth periods of faba bean crop.
Source: Authors' determination.

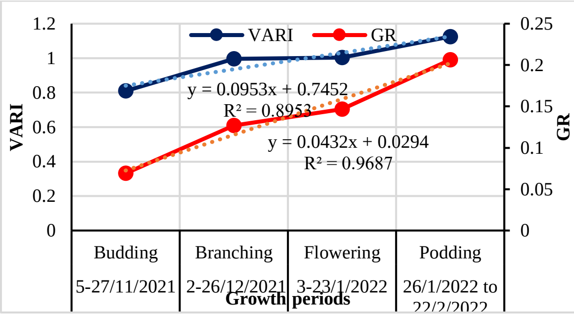


Fig. 2. Relationship between visible atmospherically resistant index and Simple red–green ratio during growth periods of faba bean crop.
Source: Authors' determination.

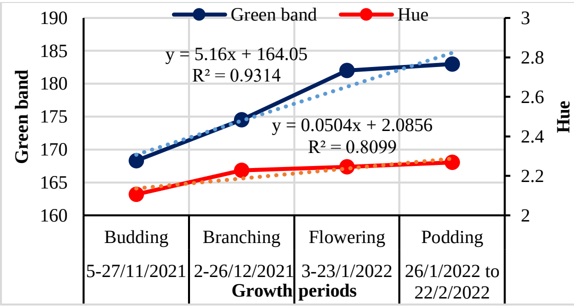


Fig. 3. Relationship between green band and hue during growth periods of faba bean crop
Source: Authors' determination.

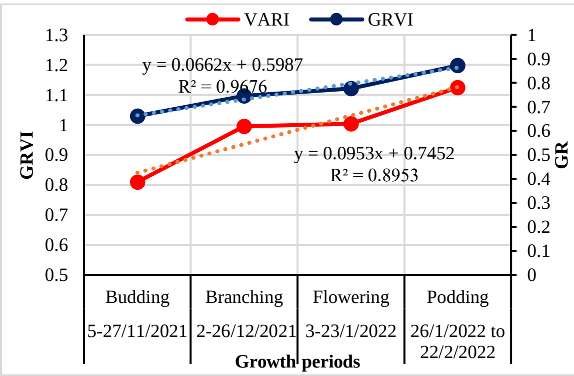


Fig. 4. Relationship between green–red vegetation index and visible atmospherically resistant index during growth periods of faba bean crop.
Source: Authors' determination.

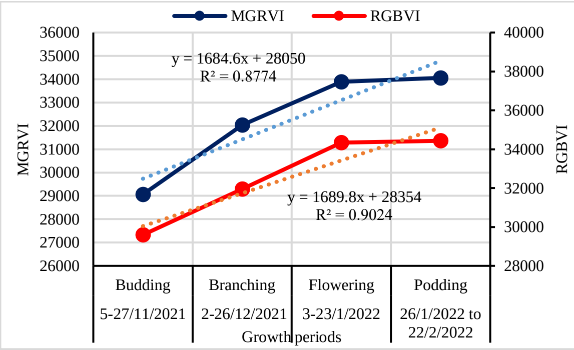


Fig. 5. Relationship between modified green–red vegetation index and RGB-based vegetation index during growth periods of faba bean crop.
Source: Authors' determination.

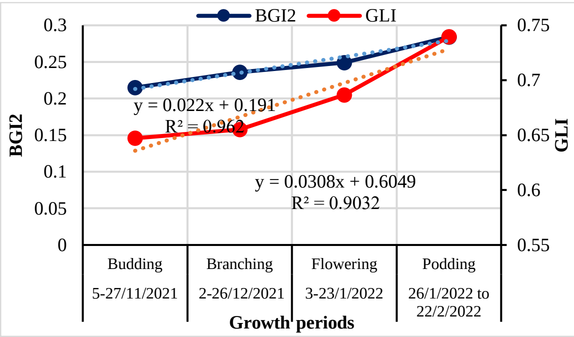


Fig. 6. Relationship between simple blue–green ratio and green leaf during growth periods of faba bean crop
Source: Authors' determination.

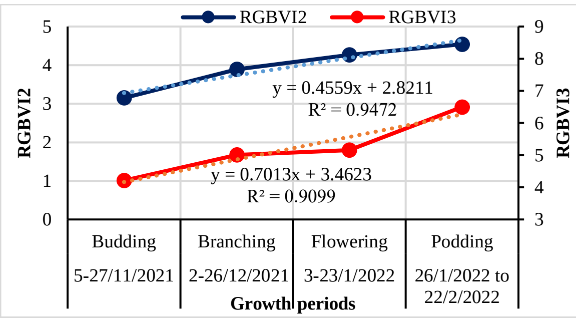
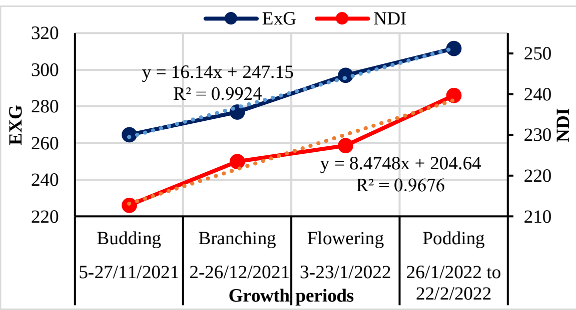


Fig. 7. Relationship between RGB-based vegetation index 2 and RGB-based vegetation index 3 during growth periods of faba bean crop.
Source: Authors' determination.



FFig. 8. Relationship between excess green index and normalized difference index during growth periods of faba bean crop.
Source: Authors' determination.

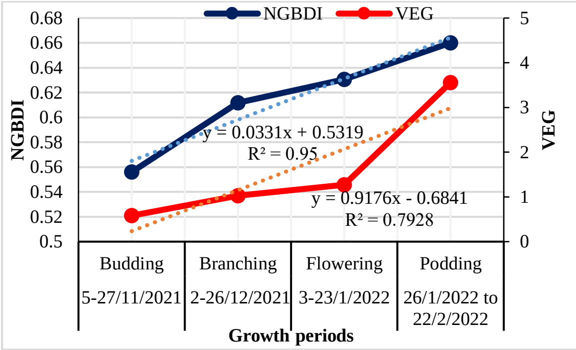


Fig. 9. Relationship between normalized green-blue difference index and vegetative during growth periods of faba bean crop
Source: Authors' determination.

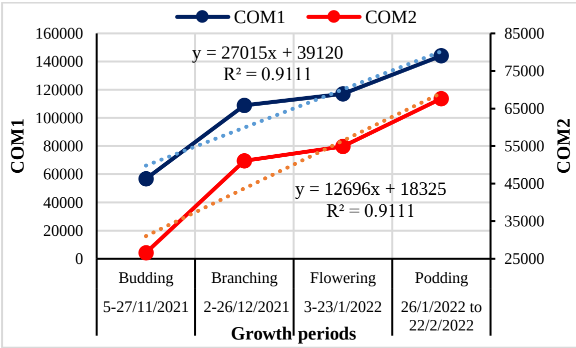


Fig. 10. Relationship between combined indices 1 and combined indices 2 during growth periods of faba bean crop
Source: Authors' determination.

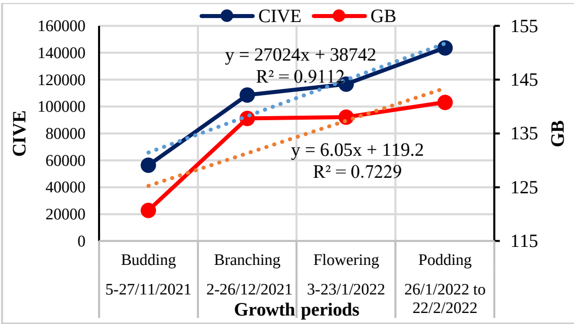


Fig. 11. Relationship between green minus blue and color index of vegetation extraction during growth periods of faba bean crop
Source: Authors' determination.

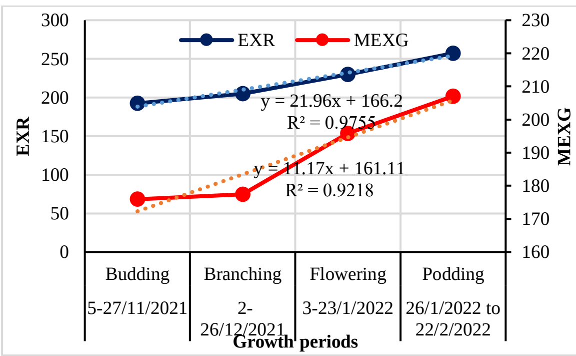


Fig. 12. Relationship between excess green index and modified excess green index during growth periods of faba bean crop
Source: Authors' determination

Table 2. The RGB vegetation index value during faba bean growth stage

Vegetation indices	Growth periods							
	Germination	Branching	Flowering	Podding	GB%	BF%	FP%	GP%
GR	0.06	0.12	0.14	0.20	50	14.28	30	70
GRVI	168.30	174.50	182.00	183.00	3.55	4.12	0.5464	8.03
RGBVI	0.66	0.74	0.77	0.87	10.81	3.89	11.494	24.13
MGRVI	29,594.85	31,950.2	34,335.66	34,432.48	7.37	6.94	0.2812	14.04
VARI	29,061.97	32,033.65	33,890.78	34,058.19	9.27	5.47	0.4915	14.66
BGI2	0.80	0.99	1.00	1.12	19.19	4.80	1.7857	28.57
VEG	0.214	0.23	0.24	0.28	6.95	4.16	14.286	23.57
GLI	0.58	1.02	1.27	3.00	43.13	19.68	57.667	80.66
ExG	0.64	0.65	0.68	0.73	1.53	4.41	6.8493	12.32
NGBDI	264.50	276.90	297.00	311.60	4.47	6.76	4.6855	15.11
RGBVI2	0.55	0.61	0.63	0.66	9.83	3.17	4.5455	16.66
RGBVI3	3.14	3.88	4.26	4.54	19.07	8.92	6.1674	30.83
Hue	4.20	5.00	5.15	6.49	16	2.91	20.647	35.28
I	2.10	2.22	2.24	2.26	5.40	0.89	0.885	7.07
ExR	79.13	80.13	82.20	83.00	1.24	2.51	0.9639	4.66
NDI	192.40	204.80	230.00	257.20	6.05	10.95	10.575	25.19
CIVE	212.72	223.48	227.41	239.66	4.81	1.72	5.1114	11.24
ExGR	56,343.80	108,519.024	116,628.052	143,721.64	48.00	6.95	18.851	60.79
COM1	54.40	6.70	72.10	72.13	18.80	7.07	0.0416	24.58
COM2	56,713.36	108,884.29	116,965.68	144,071.22	47.91	6.90	18.814	60.63
MExG	26,594.36	51,111.00	54,910.57	67,648.95	47.96	6.91	18.83	60.68
GB	175.93	177.71	195.26	207.07	1.00	8.98	5.7034	15.03
GR	120.70	137.80	138.00	140.80	12.40	0.14	1.98	14.27

Source: Author's determination.

Table 3. Model performance comparison vegetation index value during faba bean growth stage

Indices	Model performance
Simple red–green ratio	y = 0.0432x + 0.0294 R^2 = 0.9687
Green–red vegetation index	y = 0.0662x + 0.5987 R^2 = 0.9676
RGB-based vegetation index	y = 1689.8x + 28354 R^2 = 0.9024
Modified green–red vegetation index	y = 1684.6x + 28050 R^2 = 0.8774
Visible atmospherically resistant index	y = 0.0953x + 0.7452 R^2 = 0.8953
Simple blue–green ratio	y = 0.022x + 0.191 R^2 = 0.962
Vegetative	y = 0.9176x - 0.6841 R^2 = 0.7928
Green leaf	y = 0.0308x + 0.6049 R^2 = 0.9032
Excess green index	y = 16.14x + 247.15 R^2 = 0.9924
Normalized green-blue difference index	y = 0.0331x + 0.5319 R^2 = 0.95
RGB-based vegetation index 2	y = 0.4559x + 2.8211 R^2 = 0.9472
RGB-based vegetation index 3	y = 0.7013x + 3.4623 R^2 = 0.9099
Hue	y = 0.0504x + 2.0856 R^2 = 0.8099
Intensity	y = 1.3667x + 77.7 R^2 = 0.9707
Excess Red Index	y = 5.82x + 51.85 R^2 = 0.809
Normalized Difference Index	y = 8.4748x + 204.64 R^2 = 0.9676
Colour Index of Vegetation Extraction	y = 27024x + 38742 R^2 = 0.9112
Excess Green Minus Excess Red Index	y = 21.96x + 166.2 R^2 = 0.9755
Combination of green indices	y = 27015x + 39120 R^2 = 0.9111
	y = 12696x + 18325 R^2 = 0.9111
Modified Excess Green Index	y = 11.17x + 161.11 R^2 = 0.9218
Green minus Blue	y = 6.05x + 119.2 R^2 = 0.7229

Source: Author's determination.

CONCLUSIONS

The research showed the possibility of RGB vegetation index is valuable in assessing the crop's growth stage and general crop health.

The vegetation index can reflect the growth conditions of crops with using integrating image processing techniques with vegetation indicators to monitor the faba bean crop during growth periods as well as obtain information about the accuracy of vegetation analysis. The results showed increased values of color vegetation indices during fourth stages of faba bean growth from 3.55 to 8% for green band, 1.24 to4.65% for intensity, 5.4 to 7.13% for Hue, 18.8 to 24.5% for EXGR, 11.26 to

24.12% for GRVI, 18.6 to 28% for VARI, 4.8 to 11.24% for NDI, 4.47 to 15.11% for EXG, 43.48 to 83.66% for VEG, 48 to 60.7% for CIVE, and from 5.82 to 14.31% for MEXG respectively.

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