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DISTINGUISHING HEAVY METALS CONCENTRATION IN GREEN LEAFY VEGETABLES BY USING THE RGB COLOR MODEL

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Abstract

The objective of this research was to study of the correlation between RGB colour indicators and lead concentration in leafy plants. Cabbage and lettuce crops were watered with 3 levels of Lead Pb-contaminated (2.4 and 6 mg/lit). To distinguish the heavy metal contamination and their impact on vegetative characteristics for plants, the results showed with the levels of poisoning (0,2,4, and 6 mg/lit) showed the maximum value of Hue and vegetative were 0.76. and 0.032, also showed the minimum value for the same indices were 2.15 and 1.51. Also with the levels of poisoning (0,2,4, and 6mg/lit) showed the maximum value of simple red–green ratio and Green–red vegetation index was 1.61. and 0.23, also showed the minimum value for the same indices were 1.28 and 0.12. for Cabbage crops while for lettuce the results showed with the levels of poisoning (0, 2, 4, and 6 mg/lit) showed the maximum value of Hue and vegetative were 0.71. and 0.027, also showed the minimum value for the same indices were 0.41 and 0.024. Also with the levels of poisoning (0,2,4, and 6 mg/lit) showed the maximum value of simple red–green ratio and Green–red vegetation index was 1.65. and 0.43, also showed the minimum value for the same indices were 1.6 and 0.2. Linear regression analysis was performed on the equations to predict the monitoring Hue and vegetative and simple red–green ratio and Green–red vegetation index The red, green, blue band and intensity, the simple blue–green ratio addition to visible atmospherically resistant index simple green leaf and normalized green-blue difference index The RGB-based vegetation index 2 and RGB-based vegetation index 3 at different poisoning levels. The existence of a strong relationship between them and contains a high coefficient of determination.

Key words**:** *cabbage and lettuce, lead, concentration, RGB, colour, indicators*

INTRODUCTION

Vegetable crops grown in water contaminated with heavy metals differ markedly in the pattern of mineral accumulation, uptake, and distribution. Some types of crops show a marked difference in the mineral concentration of different parts of the plant. Based on the accumulation of minerals in the edible parts and whole plants, Green Leafy Vegetables recorded the highest accumulation of almost all heavy metals.

Levels of heavy metals in the soil increased significantly with increasing application rates. The controls for both plants recorded the lowest heavy metal uptake. Cabbage had an uptake of 0.48 ± 0.13, 1.36 ± 0.23, and 2.60 ± 0.29 mg/kg for Pb, Zn, and Cu, respectively, while lettuce had 0.34 ± 0.19, 1.35 ± 0.31, and 2.30 ± 0.14 mg/kg uptake for Pb, Zn, and Cu, respectively. Highest metal uptake was recorded at the highest application rate in both plants (0.66 ± 0.17, 2.66 ± 0.09, and 4.33 ± 0.14 mg/kg for Pb, Zn, and Cu, respectively, for cabbage and 0.54 ± 0.01, 2.24 ± 0.17, and 3.88 ± 0.19 mg/kg of Pb, Zn, and Cu, respectively, for lettuce). The uptake of Zn and Cu was significant, while Pb uptake was insignificant for both plants [7].

The concentrations of Pb, Cd and Ni in the edible parts of some vegetables were higher than their permissible limit levels. Therefore, the edible parts of lettuce and spinach plants are not safe for human consumption. It is worthy to mention that irrigated edible vegetable crops irrigated with sewage wastewater should be avoided and Egyptian guidelines should be developed for the reuse of these waters in agriculture [5].

There was a direct positive correlation between the zinc and lead levels in soils with the levels in vegetables. Such relation was absent for the other heavy metals. Considering an average daily intake of only 202g of fresh vegetables per person per day, all the vegetables grown at Tabata and Buguruni had lead concentration which would be a health hazard for human consumption [9].

Presence of heavy metal in randomly collected samples of green leafy from various stations of Bengaluru city was detected. Heavy metals (cadmium, zinc, copper, iron, chromium, nickel and lead) were analyzed by tri-acid digestion method [1].

The RGB color images collected by the drone can make the distribution of Kimchi cabbage readable with the naked eye, but it is necessary to convert these data to numerical cover in order to calculate and quantitatively evaluate the variation in vegetation. Assessing variations in vegetation cover should be preceded by the process of separating Kimchi cabbage and soil. In general, ground DSM assesses agricultural land before or after vegetable crops are planted. In addition, the use of drones and sensors can reduce errors related to the subjective judgment of observers, such that quality information related to cabbage growth can be obtained. This highly reliable Kimchi cabbage growth stage prediction model will help to produce basic data to inform adaptation strategies in the agricultural sector under climate change scenarios [8].

Leafy vegetables namely spinach, amaranthus, mustard and fenugreek recorded higher accumulation of both essential and non-essential heavy metals, except cadmium (Cd) and nickel (Ni) which showed less accumulation in fenugreek. Potato and onion showed lower accumulation of zinc, copper and higher accumulation of cadmium and nickel. Cauliflower and cabbage, however, showed greater accumulation of lead and nickel but less accumulation of copper and cadmium. Among fruit type vegetables, pea, soybean and cluster bean showed greater accumulation of Pb and Ni and very less accumulation of Cd [13].

The results of the present analysis showed that the concentration of Pb in the leaves of spinach, coriander, lettuce, radish, cabbage and cauliflower from the vicinity of industrial areas of Faisalabad, Pakistan were 2.251, 2.652, 2.411, 2.035, 1.921 and 1.331 mg kg-1, respectively. Pb contents in the leaves of coriander were significantly ($p<0.05$) higher as compared to those in the other vegetables, whereas, the leaf samples of cauliflower were found to be significantly ($p<0.05$) lower in Pb contents [6].

Pb toxicity causes retarded growth and inhibits germination. Plants faced with lead toxicity have their photosynthetic pathways adversely affected as it disrupts ultrastructure of chloroplast and blocks synthesis of essential pigments including chlorophyll and carotenoids in addition to plastoquinone. The nonspecific symptoms of Pb toxicity are stunted growth, chlorosis and reduced root lengths. Once entered into the cell, Pb changes cell membrane permeability, hormonal changes, inhibition of various enzymes [12].

To quantify heavy metal levels and compare their accumulation in the stems, leaves and roots of *Lactuca sativa* (lettuce), *Brassica oleracea L. varcapitata* (cabbage) and *Daucus carrota varsativa (*carrot) irrigated with wastewater from Nagodi mining site. The highest concentration (0.221 mg/Kg) of Cu was found in D. carrota roots and the highest concentration (35.35 mg/Kg) of Zn was found in the roots of Brassica. Cd accumulation in L. sativa and B. oleracea was below detection limit (< 0.002 mg/Kg). Pb absorbed by the three genotypes was below detection limit (< 0.005 mg/Kg) [2].

The All plant-based N monitoring techniques share a fundamental limitation as a water quality protection practice. They can provide an indication of current crop N status. However, given the insensitivity of plant diagnostics to soil NO3-N availability, a sufficient tissue N value provides no indication of future N fertilization requirements and therefore cannot accurately identify fields where in-season N application can be reduced or delayed. In summary, seasonal N uptake in commercial lettuce fields averaged 145 kg·ha–1 with uptake over the last half of the growing season averaging 4 kg N/ha/d. Current commercial N fertilization rates can be reduced substantially with no reduction of crop yield. PSNT was a reliable technique on which to base N fertilization. Leaf N and midrib NO3-N monitoring were of limited value in guiding in-season N management [3].

The combined deficiency of two nutrients. Those are nitrogen and phosphorus and phosphorus and potassium. The researchers use the characteristics of Red, Green, Blue (RGB) color and Sobel edge detection for leaf shape detection. The data of plant images consist of 450 training data and 150 testing data. The results of identifying nutrient deficiencies in plants using back propagation neural networks are carried out in three tests. First, using RGB color extraction and Sobel edge detection, the researchers show 65.36% accuracy. Second, using RGB color extraction, it has 70.25% accuracy. Last, with Sobel edge detection, it has 59.52% accuracy [10].

The photosynthetic characteristics of flag leaf and the accumulation and remobilization of pre-an thesis dry mass (DM) and nitrogen (N) in vegetable organs in nine wheat cultivars under different source-sink manipulation treatments including defoliation (DF), spike shading (SS) and half spikelets removal (SR) were investigated. Results showed that the SS treatment increased the photosynthetic rate (Pn) of flag leaf in source limited cultivar, but had no significant effect on sink limited cultivar. The SR treatment decreased the Pn of flag leaf. Grain DM accumulation was limited by source in some cultivars, in other cultivars, it was limited by sink. Grain N accumulation was mainly limited by source supply. The contribution of pre-an thesis dry mass to grain yield from high to low was stem, leaf and chaff, while the contribution of pre-an thesis N to grain N from high to low was leaf, stem and chaff [14].

Developing an array of sensors and innovative technologies is important in meeting agricultural demands of a larger population. Current technology for measuring plant health or diagnosing disease is expensive, invasive, and often requires sending samples to central facilities for processing [11].

Canopy temperature variability (CTV) as the range (maximum minus minimum) of CT sensed with the infrared thermometer during a particular measurement period [4].

The main objectives of this research were The objective of this study was the possibility of using IR images to detect Lead Pb-contaminated and study of the correlation between color indicators and lead concentration for Cabbage and lettuce crops.

MATERIALS AND METHODS

Nine doses of Lead Pb were given with irrigation water during the growth period. Pb-contaminated plant was watered. The plants were irrigated with water contaminated with heavy metals and plant leaves with 4 levels of (2,4, and 6 mg/lit). Plant poisoning program with lead nitrate with 5 dose start on, Sunday 8/1/2021, end at 26/1/2021 Lettuce and cabbage crops were sprayed with three concentrations of lead nitrate as a control treatment only as follows: the first to end dose was on 8 Jan/2021, 12,17,21 and 26 Jan /2021. The plants were irrigated with water contaminated with heavy metals and Edible portions of two varieties of green vegetables, namely cabbage, and lettuce leaves, were analyzed for lead, plant leaves for this experiment were tested at Central Laboratory Tanta University laboratories.

The digital camera Canon ESO R. Featuring a high-resolution 26.2MP full-frame CMOS sensor along with a DIGIC 8 image processor, both stills and UHD 4K video can be recorded using a broad sensitivity range, from ISO 100-40000, to suit working in a variety of lighting conditions. Continuous shooting is also supported at up to 5 fps for photographing moving subjects. The sensor also facilitates an advanced Dual Pixel CMOS AF system, with 4,779 selectable on-sensor phase-detection points for quickly and accurately acquiring focus during stills and video operation.

MATLAP PC-Software for Image Analysis system it was used MATLAP program. samples were captured by digital camera, using the capture card to transferred the data and stored on the PC. The MATLAP software package was used to analyzed the images of Cabbage and lettuce. There were three bands, RGB, were derived for each image until obtaining color indices.

Vegetation Indices Basics RGB: A Vegetation Index is a single value calculated by transforming the observations from multiple RGB bands. It is used to enhance the presence of green, vegetation features and thus help to distinguish them from the other objects present in the image.

Simple Ratio (SR): This is a ratio between the reflectance recorded in the RGB bands. This is a quick way to distinguish green leaves from other objects in the scene and estimate the relative biomass present in the image. Also, this value may be very useful in distinguishing stressed vegetation from non-stressed are as follows:

The Indices Simple red–green ratio:

$\frac{R}{G}$..(1)

The Green–red vegetation index:

$\frac{G-R}{G+R}$..(2)

The RGB-based vegetation index:

$\frac{G^2-(BXR)}{G^2+(BXR)}$..(3)

The Modified green–red vegetation index

$\frac{G^2-R^2}{G^2+R^2}$..(4)

The Visible atmospherically resistant index:

$\frac{G-R}{G+R-B}$...(5)

The Indices Simple blue–green ratio:

$\frac{B}{G}$...(6)

The Vegetative Indices:

$\frac{G}{R^2XB^{(1-a)}}$; $a = 0.667$.................................(7)

The Green Leaf Indices:

$\frac{2G-R-B}{2G+R+B}$...(8)

The Excess green index:

$2G - R - B$..(9)

The Normalized green-blue difference index

$\frac{G-B}{G+B}$..(10)

The RGB-based vegetation index 2

$\frac{G-R}{B}$..(11)

The RGB-based vegetation index 3

$\frac{G+B}{R}$..(12)

The Visible Atmospheric Resistant Index

$VARI = \frac{G-R}{G+R-B}$.....................................(13)

The Hue Indices:

$$H = COS^{-1}\frac{(2R-G-B)/2}{(R-G)^2+(R-B)(COSG-B)^{0.5}}$$

....(14)

The Intensity Indices

$I = \frac{1}{3}(G+R+B)$.................................(15)

$I_2 = (R-B)/2$....................................(16)

The C++ programming language was used to build a set of algorithms to determine and predict the colorimetric indicators and to study the effect of, water and fertilization shortage. The simulation and predicting programs model written by C++.

The program model test in this study the two Cabbage and lettuce seeds in greenhouse, with sand soil, and water, Phosphor, Nitrogen fertilizer, using digital and thermal camera with MATLAP and IR soft program the programs flowchart model steps

Color Program model :using this technique to estimate the color indices to distinguish the vegetative characteristics using alternative representations of the RGB Color Model Simulation and predicting programs model written by C++ to estimate the color calcification indices.

-In put: RGB band color

-Calculate: Hue, value and saturation I_2 and $\grave{I}_2$. Red/ Green ratio, Simple red–green ratio, Green–red vegetation index, RGB-based vegetation index, modified green–red vegetation index, Visible atmospherically resistant index, Simple blue–green ratio, Vegetative, Green leaf, Excess green index, Normalized green-blue difference index, RGB-based vegetation index 2 RGB-based vegetation index 3 Visible Atmospheric Resistant Index

-Predicting and determined Color indices to monitoring toxic and protecting from plant stresses.

RESULTS AND DISCUSSIONS

Figure 1 with the levels of poisoning (0, 2, 4, and 6mg/lit) showed the maximum value of red and green bands which were 122. and 92, and also showed the minimum value for the same indices which were 115 and 71. Linear regression analysis was performed on the equations to predict the monitoring red and green band at different poisoning levels. The following equation represents the relationship.

Red band: y = 2.3x +113 $R^2 = 0.9888$
Green band: y = 6.9x +66.5 $R^2 = 0.92$

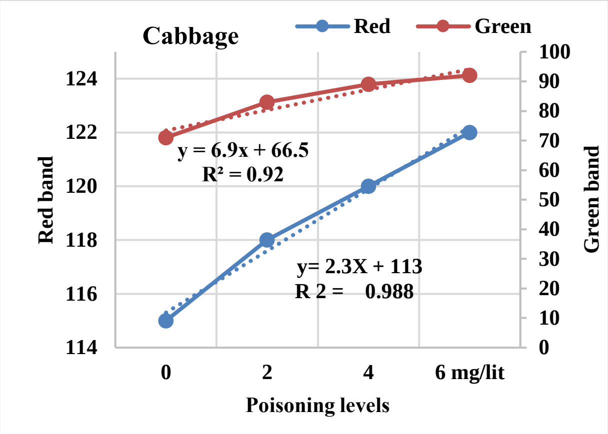

Fig. 1. The red and green band color indices with poisoning levels of cabbage crop
Source: Authors' determination.

Figure 2 with the levels of poisoning (0,2,4, and 6mg/lit) showed the maximum value of blue band and intensity which were 55. and 81.6, and also showed the minimum value for the same indices which were 28 and 79.3. Linear regression analysis was performed on the equations to predict the monitoring red band and intensity at different poisoning levels. The following equation represents the relationship.
Blue band: y = 9.1x +16.5 $R^2 = 0.9524$
Intensity: y = 0.7667x +78.667 $R^2 = 0.9888$

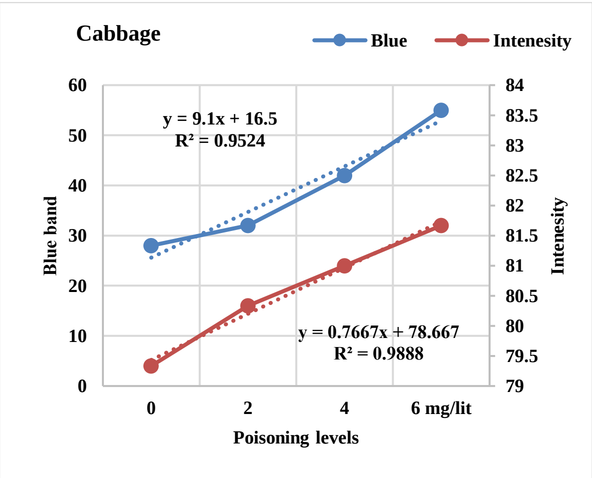

Fig. 2. The blue band and intensity with poisoning levels of cabbage crop
Source: Authors' determination.

Figure 3 with the levels of poisoning (0,2,4, and 6mg/lit) showed the maximum value of Hue and vegetative which were 0.76. and 0.032, and also showed the minimum value for the same indices which were 2.15 and 1.51. Linear regression analysis was performed on the equations to predict the monitoring Hue and vegetative at different poisoning levels. The following equation represents the relationship.
Hue: y = 0.163x +0.1557 $R^2 = 0.9201$
Vegetative: y = 0.002x +0.0241 $R^2 = 0.9811$

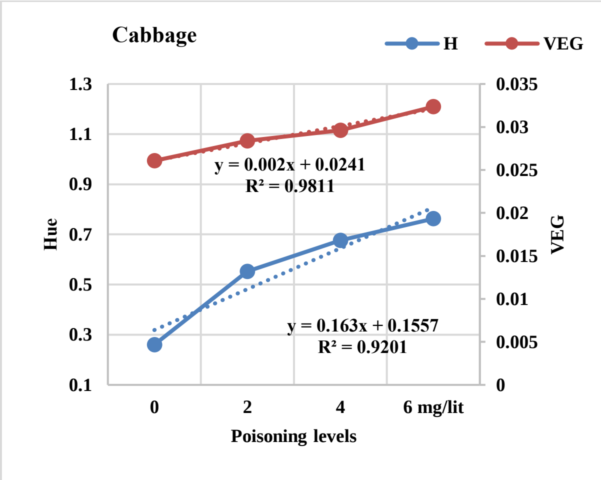

Fig. 3. The Hue and vegetative with poisoning levels of cabbage crop.
Source: Authors' determination.

Figure 4 and with the levels of poisoning (0, 2, 4, and 6mg/lit) showed the maximum value of simple red–green ratio and Green–red vegetation index which were 1.61. and 0.23, and also showed the minimum value for the same indices which were 1.28 and 0.12.

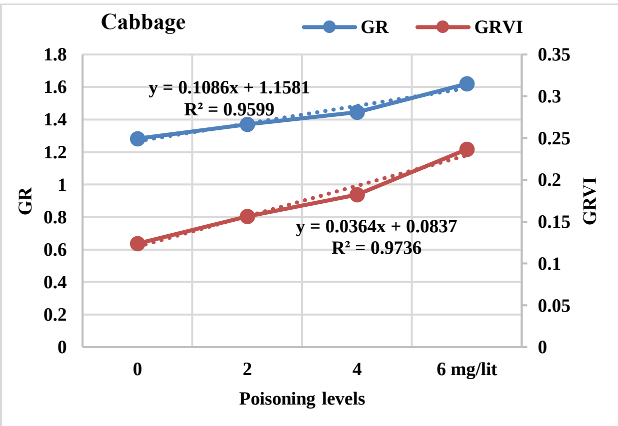

Fig. 4. The simple red–green ratio and Green–red vegetation index with poisoning levels of cabbage crop
Source: Authors' determination.

Linear regression analysis was performed on the equations to predict the monitoring simple red–green ratio and Green–red vegetation index at different poisoning levels. The following equation represents the relationship.

GR: $y = 0.1086x + 1.1581$ $R^2 = 0.9599$

GRVI: $y = 0.03649x + 0.0837$ $R^2 = 0.9736$

Figure 5 with the levels of poisoning (0, 2, 4, and 6 mg/lit) showed the maximum value of simple blue–green ratio and visible atmospherically resistant index which were 0.77 and 0.33, and also showed the minimum value for the same indices which were 0.3 and 0.14. Linear regression analysis was performed on the equations to predict the monitoring simple blue–green ratio and visible atmospherically resistant index at different poisoning levels. The following equation represents the relationship.

BGI2: $y = 0.1557x + 0.0968$ $R^2 = 0.9138$

VARI: $y = 0.0625x + 0.0671$ $R^2 = 0.9419$

Figure 6 with the levels of poisoning (0, 2, 4, and 6 mg/lit) showed the maximum value of green leaf and normalized green-blue difference index which were 0.11. and 0.52, and also showed the minimum value for the same indices which were 0.032 and 0.24. Linear regression analysis was performed on the equations to predict the monitoring green leaf and normalized green-blue difference index at different poisoning levels. The following equation represents the relationship.

GLI: $y = 0.0266x + 0.0108$ $R^2 = 0.9724$

NGBDI: $y = 0.0969x + 0.1484$ $R^2 = 0.9897$

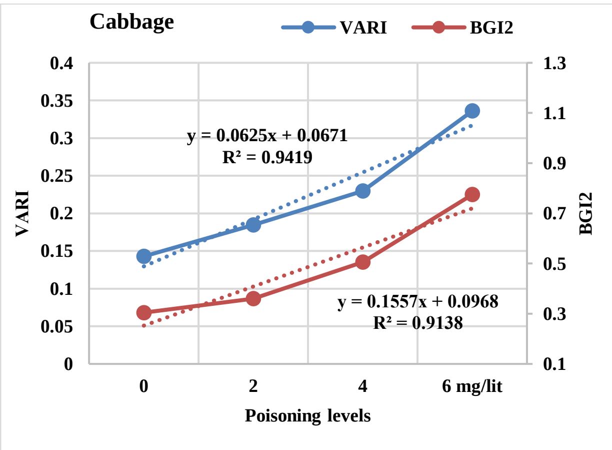

Fig. 5. The simple blue–green ratio and visible atmospherically resistant index with poisoning levels of cabbage crop
Source: Authors' determination.

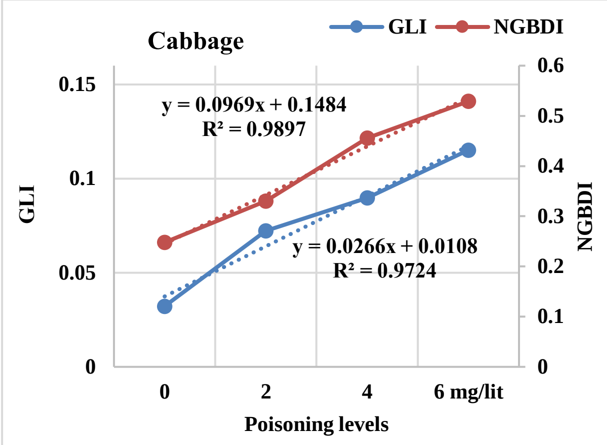

Fig. 6. The simple green leaf and normalized green-blue difference index color with poisoning levels of cabbage crop
Source: Authors' determination.

Figure 7 and with the levels of poisoning (0, 2, 4, and 6 mg/lit) showed the maximum value of RGB-based vegetation index 2 and RGB-based vegetation index 3 which were 1.03. and 7.5,and also showed the minimum value for the same indices which were 0.8 and 3.38. Linear regression analysis was performed on the equations to predict the monitoring RGB-based vegetation index 2andRGB-based vegetation index 3 at different poisoning levels. The following equation represents the relationship.

RGBVI2: $y = 0.0741x + 0.7249$ $R^2 = 0.9818$

RGBVI3: $y = 1.4115x + 2.0485$ $R^2 = 0.9859$

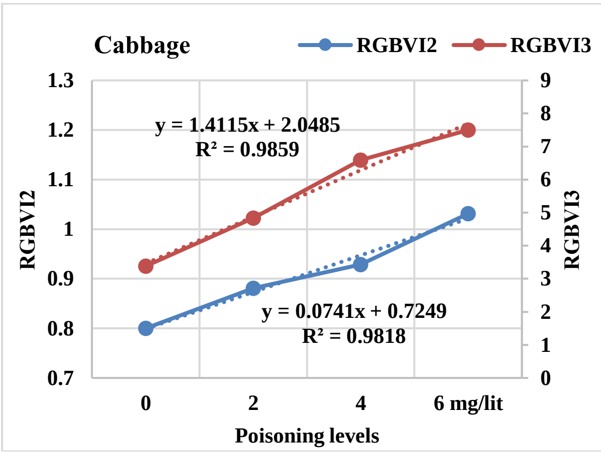

Fig. 7. The RGB-based vegetation index 2 and RGB-based vegetation index 3 color with poisoning levels of cabbage crop
Source: Authors' determination.

Figure 8 with the levels of poisoning (0,2,4, and 6mg/lit) showed the maximum value of red and green bands which were 123. and 84, and also showed the minimum value for the same indices which were 104 and63. Linear regression analysis was performed on the equations to predict the monitoring red and green band at different poisoning levels. The following equation represents the relationship.

Red band: $y = 6.5x + 98.5$ $R^2 = 0.9657$

Green band: $y = 6.79x + 55.5$ $R^2 = 0.9561$

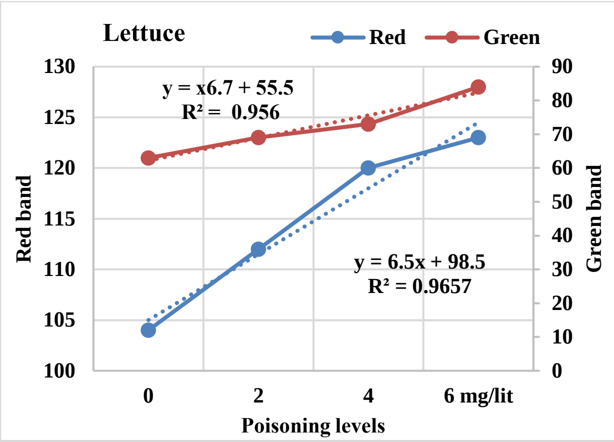

Fig. 8. The red and green band color indices with poisoning levels of lettuce crop
Source: Authors' determination.

Figure 9 with the levels of poisoning (0, 2, 4, and 6 mg/lit) showed the maximum value of blue band and intensity which were 48. and 85, and also showed the minimum value for the same indices which were 34 and 67.

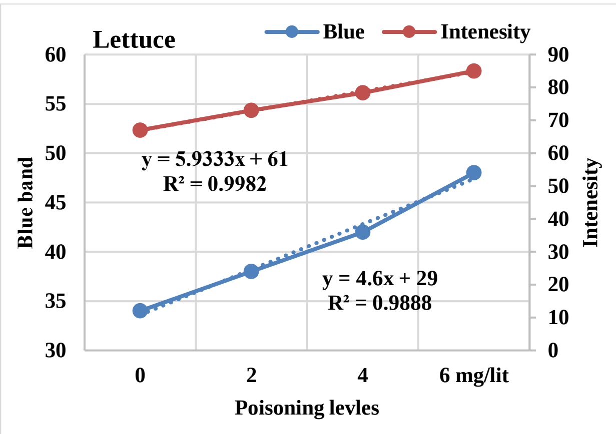

Fig. 9. The blue band and intensity color indices with poisoning levels of lettuce crop
Source: Authors' determination.

Linear regression analysis was performed on the equations to predict the monitoring red band and intensity at different poisoning levels. The following equation represents the relationship.

Blue band: $y = 4.6x + 29$ $R^2 = 0.9888$

Intensity: $y = 5.9333x + 61$ $R^2 = 0.9982$

Figure 10 with the levels of poisoning (0, 2, 4, and 6 mg/lit) showed the maximum value of Hue and vegetative which were 0.71. and 0.027, and also showed the minimum value for the same indices which were 0.41 and 0.024. Linear regression analysis was performed on the equations to predict the monitoring Hue and vegetative at different poisoning levels. The following equation represents the relationship.

Hue: $y = 0.1001x + 0.2937$ $R^2 = 0.9589$

Vegetative: $y = 0.0009x + 0.0244$ $R^2 = 0.9008$

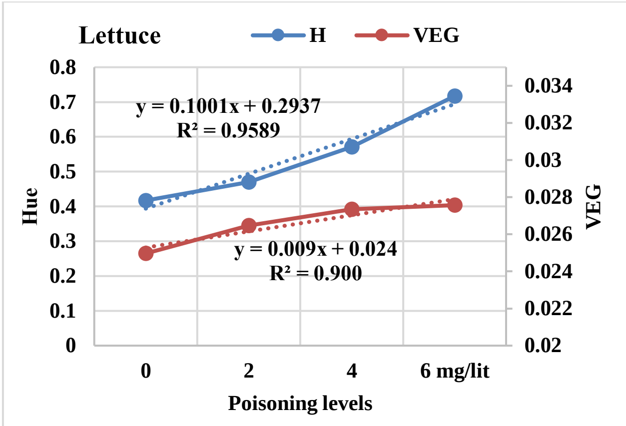

Fig. 10. The Hue and vegetative color indices with poisoning levels of lettuce crop.
Source: Authors' determination.

Figure 11 with the levels of poisoning (0, 2, 4, and 6 mg/lit) showed the maximum value of simple red–green ratio and Green–red vegetation index which were 1.65. and 0.43, and also showed the minimum value for the same indices which were 1.6 and 0.2.

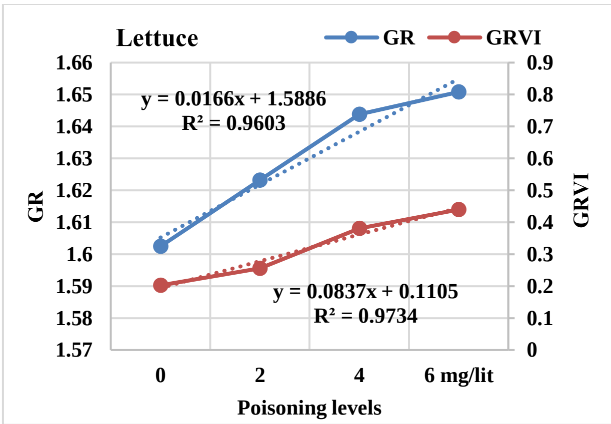

Fig. 11. The simple red–green ratio and Green–red vegetation index with poisoning levels of lettuce crop
Source: Authors' determination.

Linear regression analysis was performed on the equations to predict the monitoring simple red–green ratio and Green–red vegetation index at different poisoning levels. The following equation represents the relationship.
GR: y = 0.0166x +1.5886 R^2 = 0.9603
GRVI: y = 0.0837x +0.1105 R^2 = 0.9734
Figure 12 with the levels of poisoning (0, 2, 4, and 6 mg/lit) showed the maximum value of simple blue–green ratio and visible atmospherically resistant index which were 0.57. and 0.43, and also showed the minimum value for the same indices which were 0.53 and 0.28. Linear regression analysis was performed on the equations to predict the monitoring simple blue–green ratio and visible atmospherically resistant index at different poisoning levels. The following equation represents the relationship.
BGI2: y = 0.0128x +0.5274 R^2 = 0.9447
VARI: y = 0.0536x +0.2064 R^2 = 0.9039
Figure 13 with the levels of poisoning (0, 2, 4, and 6 mg/lit) showed the maximum value of green leaf and normalized green-blue difference index which were 0.05. and 0.52, and also showed the minimum value for the same indices which were 0.02 and 0.2. Linear regression analysis was performed on the equations to predict the monitoring green leaf and normalized green-blue difference index at different poisoning levels. The following equation represents the relationship.
GLI: y = 0.0099x +0.0122 R^2 = 0.9998
NGBDI: y = 0.1107x +0.0651 R^2 = 0.9536
(Fig. 13).

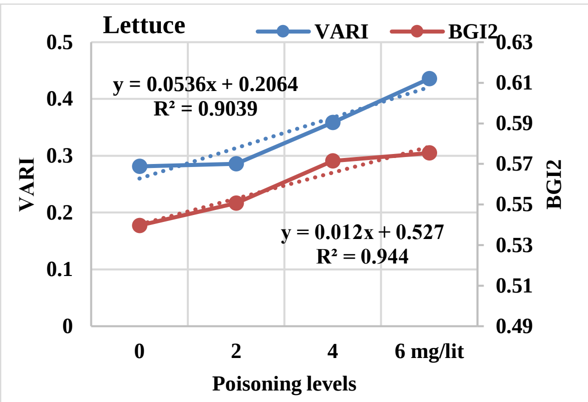

Fig. 12. The simple blue–green ratio and visible atmospherically resistant index with poisoning levels of lettuce crop
Source: Authors' determination.

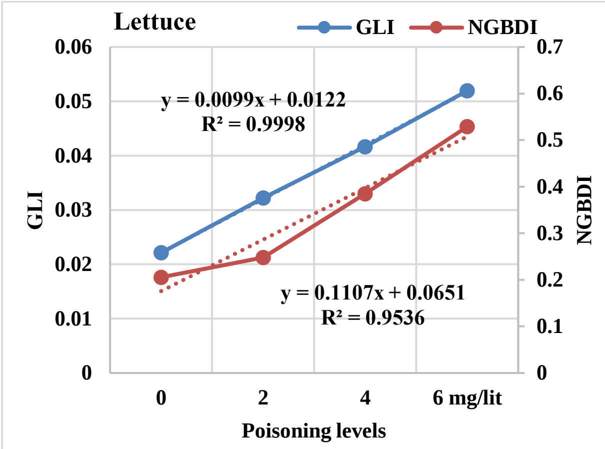

Fig. 13. The simple green leaf and normalized green-blue difference index with poisoning levels of lettuce crop
Source: Authors' determination.

Figure 14 with the levels of poisoning (0, 2, 4, and 6 mg/lit) showed the maximum value of RGB-based vegetation index 2 and RGB-based vegetation index which were 1.36. and 6.7, and also showed the minimum value for the same indices which were 0.46 and 3.1. Linear regression analysis was performed on the equations to predict the monitoring RGB-based vegetation index 2 and RGB-based vegetation index 3 at different poisoning levels.
The following equation represents the relationship.
RGBVI2: y = 0.2859x +0.1765 R^2 = 0.9709
RGBVI3: y = 1.2676x +1.9701 R^2 = 0.9554

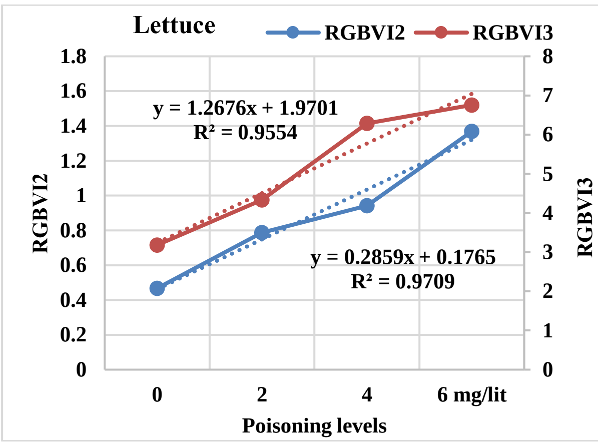

Fig. 14. The RGB-based vegetation index 2 and RGB-based vegetation index 3 with poisoning levels of lettuce crop
Source: Authors' determination.

Figure 15 with the levels of poisoning (0, 2, 4, and 6 mg/lit) showed the maximum value of red and green bands which were 123. and 84, and also showed the minimum value for the same indices which were 104 and63. Linear regression analysis was performed on the equations to predict the monitoring red and green band at different poisoning levels. The following equation represents the relationship.

Red band: y = 6.5x +98.5 $R^2 = 0.9657$
Green band: y = 6.79x +55.5 $R^2 = 0.9561$

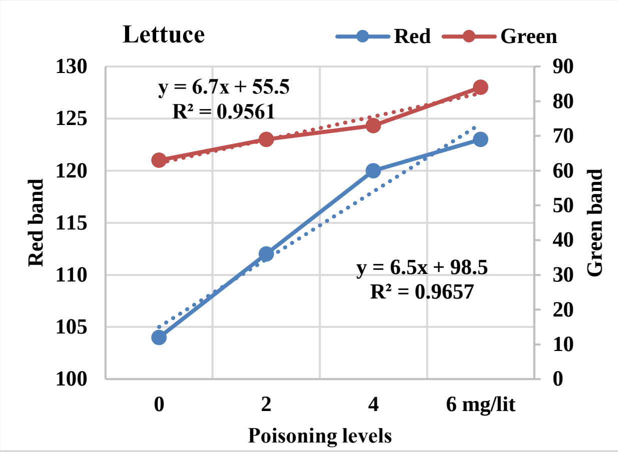

Fig. 15. The red and green band with poisoning levels of lettuce crop
Source: Authors' determination.

Figure 16 and with the levels of poisoning (0,2,4, and 6mg/lit) showed the maximum value of blue band and intensity which were 48. and 85, and also showed the minimum value for the same indices which were 34 and 67. Linear regression analysis was performed on the equations to predict the monitoring red band and intensity at different poisoning levels. The following equation represents the relationship.

Blue band: y = 4.6x +29 $R^2 = 0.9888$
Intensity: y = 5.9333x +61 $R^2 = 0.9982$

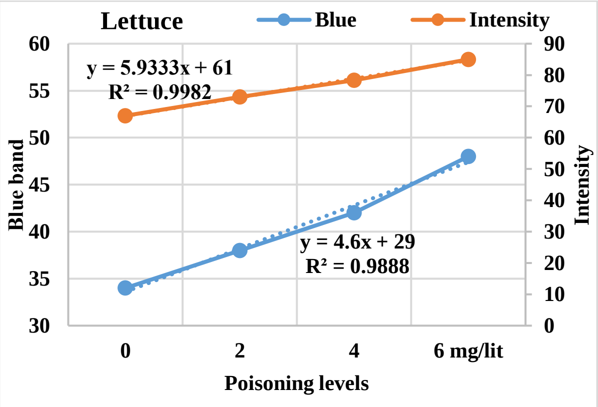

Fig. 16. The blue band and intensity color indices with poisoning levels of lettuce crop
Source: Authors' determination.

Figure 17 with the levels of poisoning (0, 2, 4, and 6 mg/lit) showed the maximum value of Hue and vegetative which were 0.71. and 0.027, and also showed the minimum value for the same indices which were 0.41 and 0.024. Linear regression analysis was performed on the equations to predict the monitoring Hue and vegetative at different poisoning levels. The following equation represents the relationship.

Hue: y = 0.1001x +0.2937 $R^2 = 0.9589$
Vegetative: y = 0.0009x +0.0244 $R^2 = 0.9008$

Figure 18 with the levels of poisoning (0, 2, 4, and 6 mg/lit) showed the maximum value of simple red–green ratio and Green–red vegetation index which were 1.65. and 0.43, and also showed the minimum value for the same indices which were 1.6 and 0. 2.

Linear regression analysis was performed on the equations to predict the monitoring simple red–green ratio and Green–red vegetation index at different poisoning levels (Fig. 18).

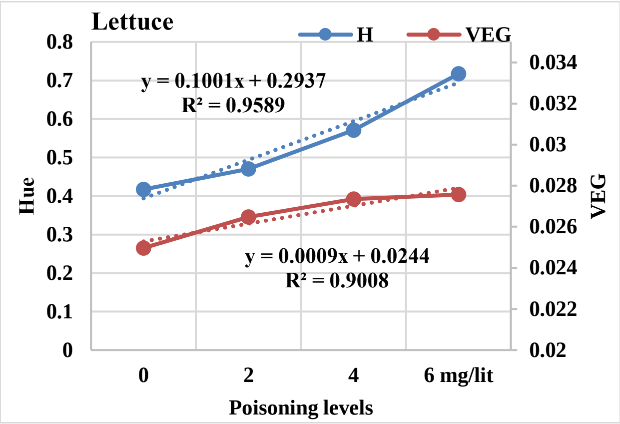

Fig. 17. The Hue and vegetative color indices with poisoning levels of lettuce crop
Source: Authors' determination.

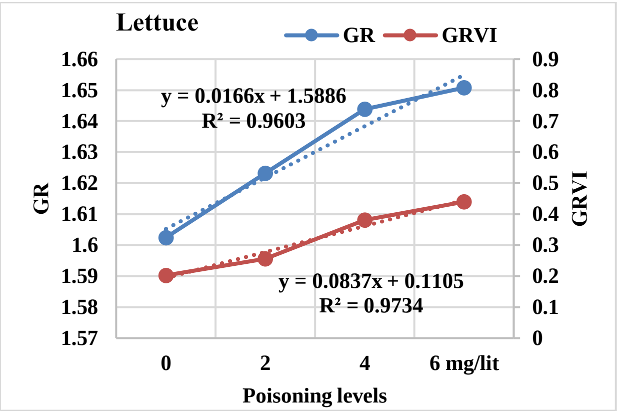

Fig. 18. The simple red–green ratio and Green–red vegetation index with poisoning levels of lettuce crop
Source: Authors' determination.

The following equation represents the relationship.

GR: y = 0.0166x +1.5886 R^2 = 0.9603

GRVI: y = 0.0837x +0.1105 R^2 = 0.9734

(Fig. 18).

Figure 19 with the levels of poisoning (0,2,4, and 6mg/lit) showed the maximum value of simple blue–green ratio and visible atmospherically resistant index which were 0.57. and 0.43, and also showed the minimum value for the same indices which were 0.53 and 0.28.

Linear regression analysis was performed on the equations to predict the monitoring simple blue–green ratio and visible atmospherically resistant index at different poisoning levels. The following equation represents the relationship.

BGI2: y = 0.0128x +0.5274 R^2 = 0.9447

VARI: y = 0.0536x +0.2064 R^2 = 0.9039

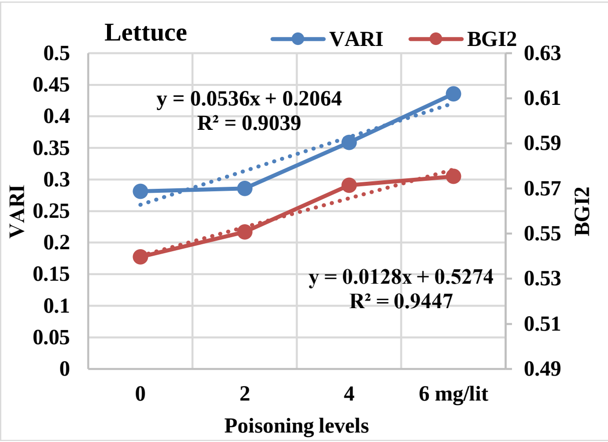

Fig. 19. The simple blue–green ratio and visible atmospherically resistant index with poisoning levels of lettuce crop

Source: Authors' determination.

Figure 20 with the levels of poisoning (0, 2, 4, and 6 mg/lit) showed the maximum value of green leaf and normalized green-blue difference index which were 0.05. and 0.52, and also showed the minimum value for the same indices which were 0.02 and 0.2. Linear regression analysis was performed on the equations to predict the monitoring green leaf and normalized green-blue difference index at different poisoning levels.

The following equation represents the relationship.

GLI: y = 0.0099x +0.0122 R^2 = 0.9998

NGBDI: y = 0.1107x +0.0651 R^2 = 0.9536

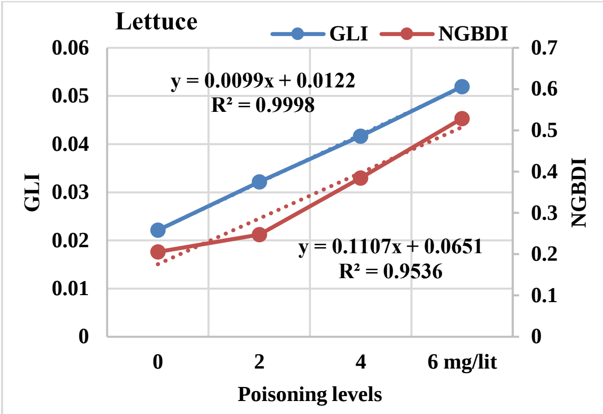

Fig. 20. The simple green leaf and normalized green-blue difference index with poisoning levels of lettuce crop

Source: Authors' determination.

Figure 21 with the levels of poisoning (0, 2, 4, and 6 mg/lit) showed the maximum value of RGB-based vegetation index 2 and RGB-based vegetation index 3 which were 1.36. and 6.7, and also showed the minimum value for the same indices which were 0.46 and 3.1. Linear regression analysis was performed on the equations to predict the monitoring RGB-based vegetation index 2 and RGB-based vegetation index 3 at different poisoning levels.

The following equation represents the relationship.

RGBVI2: y = 0.2859x +0.1765 R^2 = 0.9709

RGBVI3: y = 1.2676x +1.9701 R^2 = 0.9554

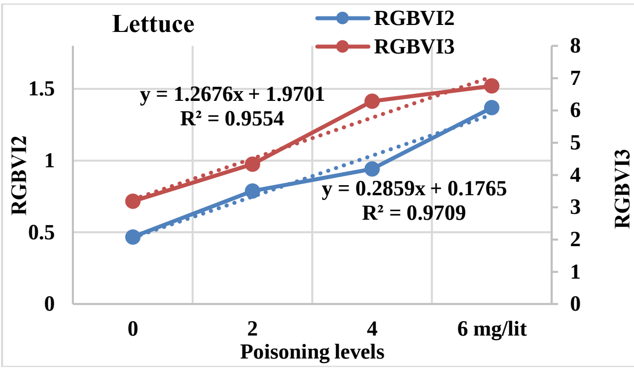

Fig. 21. The RGB-based vegetation index 2 and RGB-based vegetation index 3 with poisoning levels of lettuce crop

Source: Authors' determination.

CONCLUSIONS

The study showed the correlation between RGB color indices and lead concentration in leafy plants. To distinguish heavy metal pollution and its effect on vegetative characteristics, for plants, the results showed that with toxicity levels. Linear regression analysis was performed on the equations to predict the monitoring Hue and vegetative and simple red–green ratio and Green–red vegetation index The red, green, blue band and intensity. The simple blue–green ratio addition to visible atmospherically resistant index simple green leaf and normalized green-blue difference index The RGB-based vegetation index 2 and RGB-based vegetation index 3 at different poisoning levels. The existence of a strong relationship between them and contains a high coefficient of determination

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