

Full Length Research Paper

Use of improved hue, luminance and saturation (IHLS) color space in the estimation of Nitrogen on tomato seedlings (*Lycopersicon esculentum*)

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Measuring deficiencies in the nutrition of crops is important because it allow growers to take proper action on time so as to get better development of plants. Several methods have been proposed in the measurement of nitrogen. One of those methods is image processing using color spaces. In this study, five levels of deficiency of nitrogen were induced for the evaluation in tomato seedlings. Color images were taken with a digital camera. These images were processed in Visual C++ making segmentation of the images, and for its analysis they were converted from red, green, blue (RGB) to improved hue, luminance and saturation (IHLS) color space. Luminance, saturation, hue and hue-saturation components on IHLS were proposed in the nitrogen diagnostic. Results from laboratory on the tomato leaves were taken as reference. To evaluate the data, linear regression and variance analysis with Tukey test ($p < 0.01$) were made. Hue was the value that had better correlated laboratory values obtaining $R^2 = 0.86$. Nitrogen estimation by this method in tomato seedlings is fast and economic and it has an advantage in relation to other proposed methods in RGB color spaces that it is less susceptible to changes of illumination.

Key words: Nitrogen deficiency, leaves, IHLS color space, hue, tomato.

INTRODUCTION

One problem in crops is to take care of the nutrition requirements, because the quality of the product depends largely on the fertilization levels. Also, it is to make proper use of chemical fertilizers, decrease the environmental pollution, reduce production costs and others (Badr and El-Yazied, 2007; Wiwart et al., 2009). For the chemical elements, one of the most important in the development of plants is the nitrogen (N) (Rico-García et al., 2009). The N deficiency in tomato plants reduces the leaf area and leaves number (Badr and El-Yazied, 2007; Buyukbay

et al., 2011). For preventing N deficiency, it can be diagnosed promptly. Several methods have been proposed in N diagnostic for different crops. Between the methods is the soil plant analysis development (SPAD) instrument for measuring chlorophyll; however, its cost is very high and measurements are not reliable. In the measurements, the SPAD uses a small area on the leaf (6 mm^2) (Pagola et al., 2009; Mercado-Luna et al., 2010). Recently, other methods have been proposed based on color evaluation by image processing, using color spaces. Wiwart et al. (2009), used the color space hue, saturation, intensity (HIS) and $L^*a^*b^*$ (<http://www.easyrgb.com/index.php?X=MATH>) to assess macronutrients (N, P, K and Mg), in plants using the Euclidean distance to measure color differences. Mercado-Luna (2010) used the color space Red, Green,

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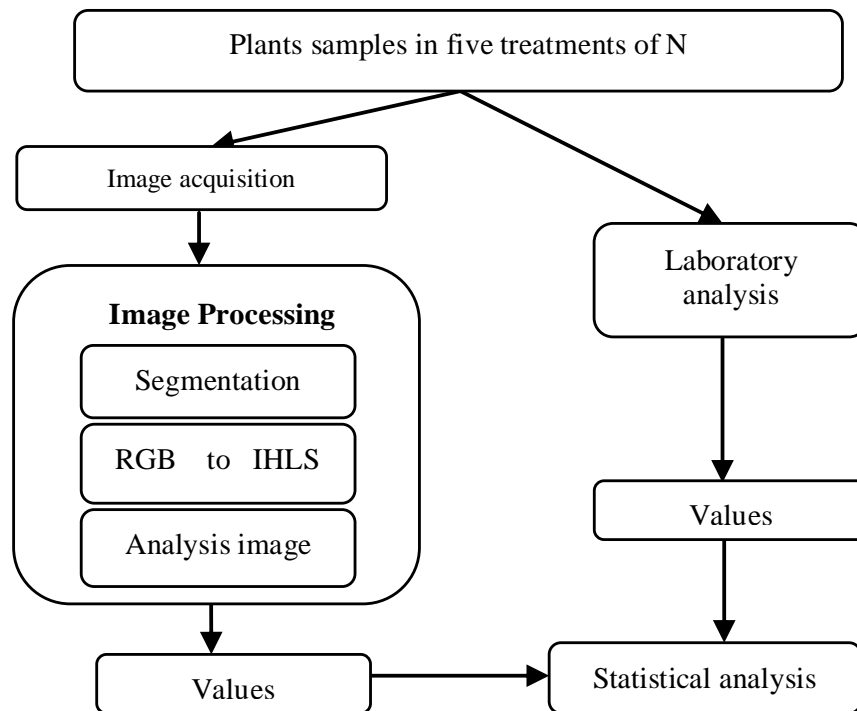


Figure 1. General methodology in the estimation of N.

Blue (RGB) in the estimation of N on tomato seedlings. However these color spaces were designed for computer graphics and not for image processing. Light affects these color spaces (Hasan, 2004). Hanbury and Serra (2003) improved the color space HLS (hue, luminance, saturation) creating the improved, hue, luminance and saturation (IHLS) by removing the normalization of the saturation. In this color space the saturation and luminance are always independent and the saturation of achromatic pixels is always low. It also allows a quantitative analysis of the image (Blauensteiner et al., 2006). Taking into account these advantages we proposed the IHLS color space to develop a new image processing methodology to estimate N deficiency in tomato seedlings.

MATERIALS AND METHODS

The experimental site is located in Queretaro State University, Amazcala campus, Queretaro, Mexico at a longitude of 100° 16' W; latitude of 20° 42' N; and altitude of 1920 m. The general methodology for this work is presented in Figure 1, which represents the two ways of estimating N content on tomatoes leaves from pictures.

Data set

The images used for the measurements were taken from the research of Mercado-Luna et al. (2010). In this work five N treatments: 0, 4, 8, 12 and 16 me/L with six replications each were

applied to an experimental unit. 10 images from each repetition were taken, in total 300 images were evaluated in the study. Also a representative sample of six plants from each treatment was sent to the laboratory for determinations of N content.

The images were taken inside a dark room with a white light source (lamp of 100 watts) 40 cm of distance from the base. The background in the base was white color. The camera used was a SONY cyber-shot model DSC-W 120 with 7.2 megapixels of resolution.

Image processing methodology

The images were converted from JPEG to BMP format using Paint (Windows vista) and the image processing methodology was implemented in Visual C++ 6.0.

Segmentation

The images were converted to gray scale with the average of the RGB components in each pixel. Otsu algorithm was used to obtain the optimal threshold level (Femat-Diaz et al., 2011). This maximizes the variance between classes with a searching in the gray levels. With the obtained threshold level the image was binarized (Figure 2b). Median filter was applied to eliminate the noise. Considering that the background for the segmented image was black and white, color leaves were discriminated from the background (Figure 2c).

Color space conversion RGB to IHLS

The segmented image was converted from RGB color space to IHLS by the formulae (1), (2), (3) according to Angulo and Serra

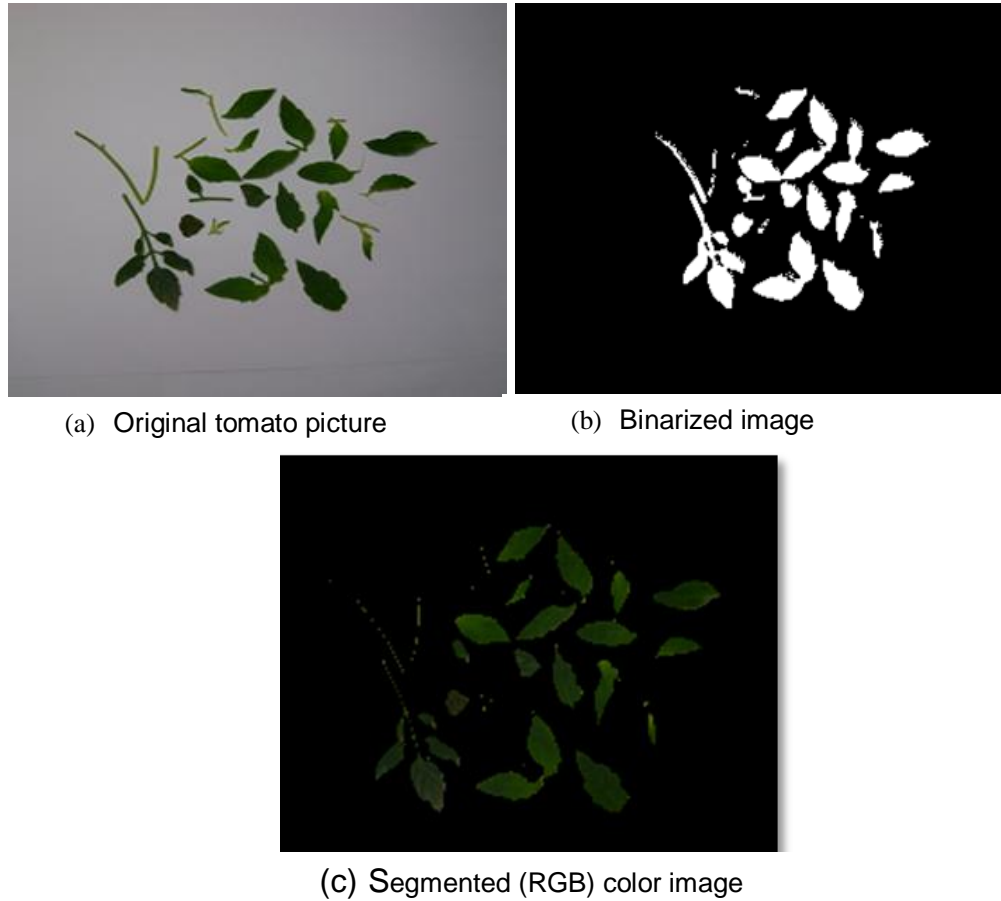


Figure 2. Segmentation process in tomato images.

(2005), where IHLS space is represented in polar coordinates.

$$l = 0.213 * r + 0.715 * g + 0.072 * b \tag{1}$$

$$s = \max(r, g, b) - \min(r, g, b) \tag{2}$$

$$h = \begin{cases} \frac{g-b}{(\max(r,g,b) - \min(r,g,b))} & \text{if } r = \max(r, g, b) \\ \frac{b-r}{(\max(r,g,b) - \min(r,g,b))} + 2 & \text{if } g = \max(r, g, b) \\ \frac{r-g}{(\max(r,g,b) - \min(r,g,b))} + 4 & \text{if } b = \max(r, g, b) \end{cases} \tag{3}$$

Where:

l = luminance

s = saturation

h = hue

r = component R in the RGB space

g = component G in the RGB space

b = component B in the RGB space

According to Angulo and Serra (2005), the values obtained of hue are multiplied by one constant $k=60$, to determine the unit of work on angular grades; each grade corresponds to a tone in the color

space IHLS. The IHLS color space is obtained by placing an *achromatic axis* through all the grey ($R = G = B$) points in the RGB color cube, and then specifying the coordinates of each point in terms of position on the achromatic axis (brightness), distance from the axis (saturation s), and angle with respect to pure red (hue θ_H) (Hambury and Serra, 2003). Luminance, from 0-255; saturation, from 0-255 and hue is an angular measurement from 0-360°.

N estimation

Estimation N was based on components (hue, luminance, saturation) histograms in IHLS and in the fusion of saturation and hue.

N estimation based on histograms

One histogram from each component (hue, luminance and saturation) in color space IHLS was made (Figure 3). From it a sum was made of the frequency for each component multiplying each one of the values by its frequency. The result was divided by the total number of pixels representing the leaves in pictures, obtaining an average (Equations 4, 5 and 6).

$$\text{Hue average: } ah = \frac{\sum_{i=0}^{i<360} f_h * i}{tp} \tag{4}$$

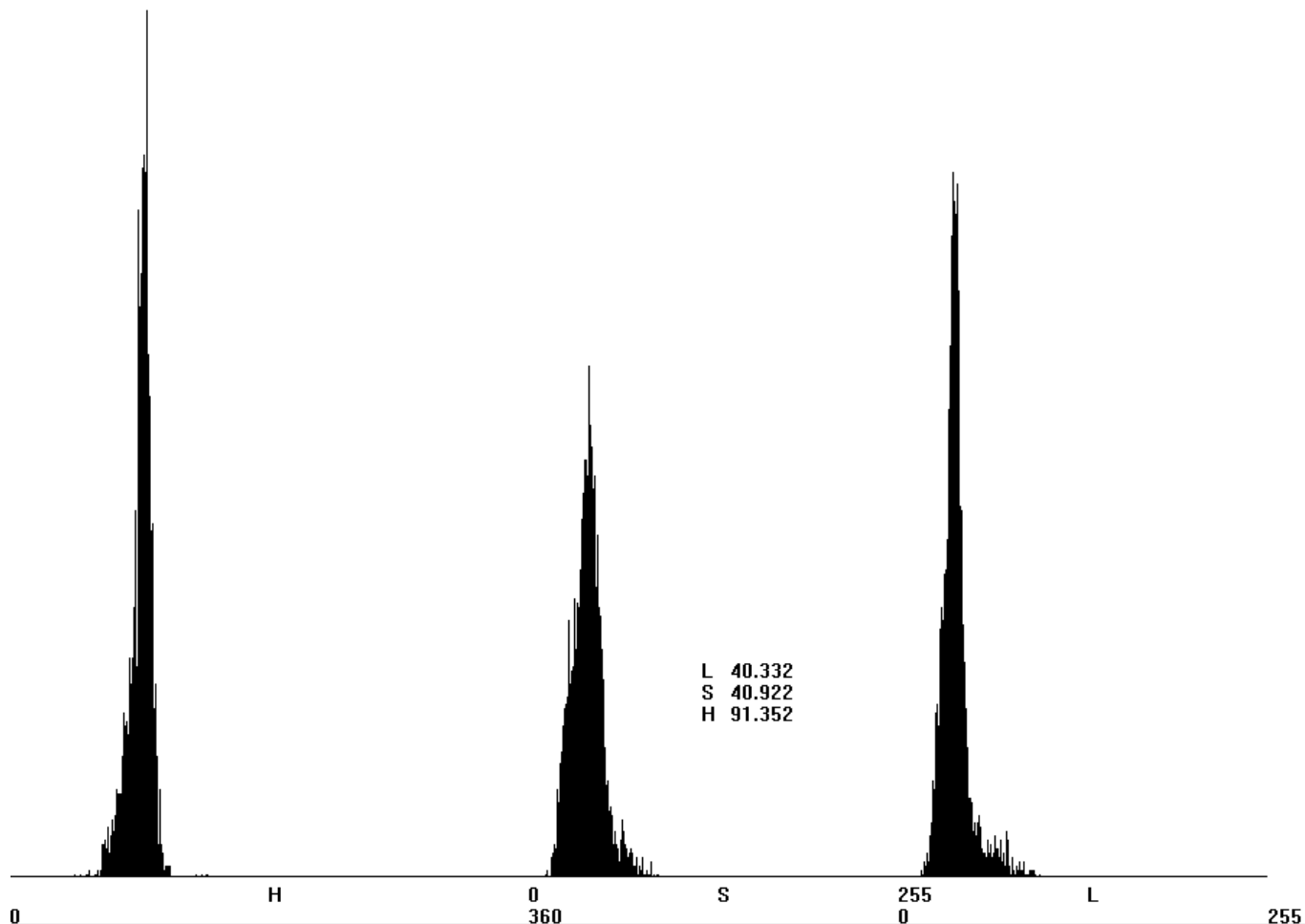


Figure 3. Luminance (L), Saturation (S) and Hue (H) Histogram.

Luminance average: $al = \frac{\sum_{i=0}^{i<255} f_l * i}{tp}$ (5)

Saturation average: $as = \frac{\sum_{i=0}^{i<255} f_s * i}{tp}$ (6)

Where:

- f_h = frequency of each value on hue
- f_l = frequency of each value on luminance
- f_s = frequency of each value on saturation
- t_p = pixels total corresponding a leaves in the picture
- ah = average of hue on leaves
- al = average of luminance on leaves
- as = average of saturation on leaves

N estimation from fusion of saturation-hue

For each pixel of the image, saturation and hue was calculated. These values were treated using Equation 7.

Fusion saturation-hue: $ash = \frac{\sum_{i=0}^{i<max} \sqrt{(s * cosH)^2 + (s * sinH)^2}}{tp}$ (7)

Where:

- ash = average of saturation and hue on leaves
- t_p = pixels total corresponding a leaves in the picture
- m = columns in the picture
- n = rows in the picture
- s = saturation
- H = hue in angular grades

Statistical tests

Statistical analyses were made in OriginLab 8. The tests applied were ANOVAs with a Tuckey test of $p<0.01$. Linear correlations were also performed between values obtained from each methodology and values from laboratory.

RESULTS

The estimation of N in tomato seedlings by image processing using color space IHLS was evaluated using

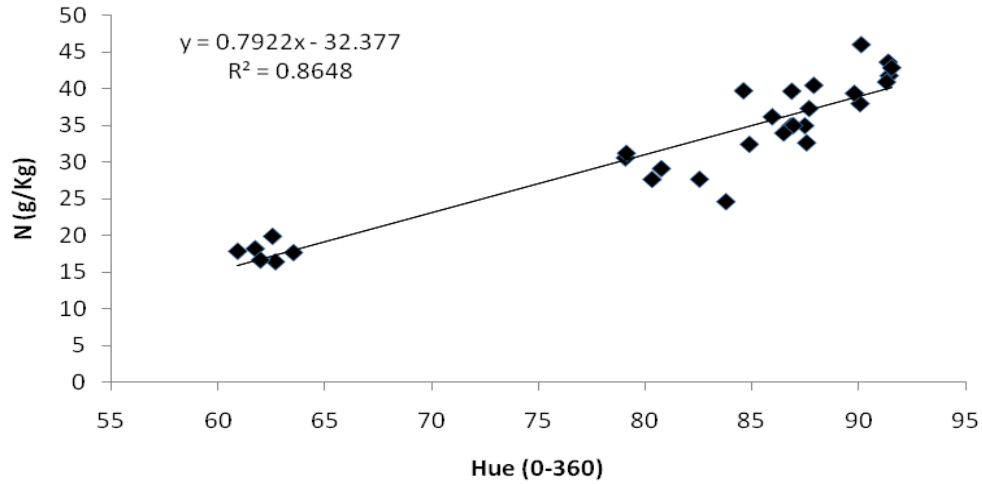


Figure 4. Linear model from hue and N.

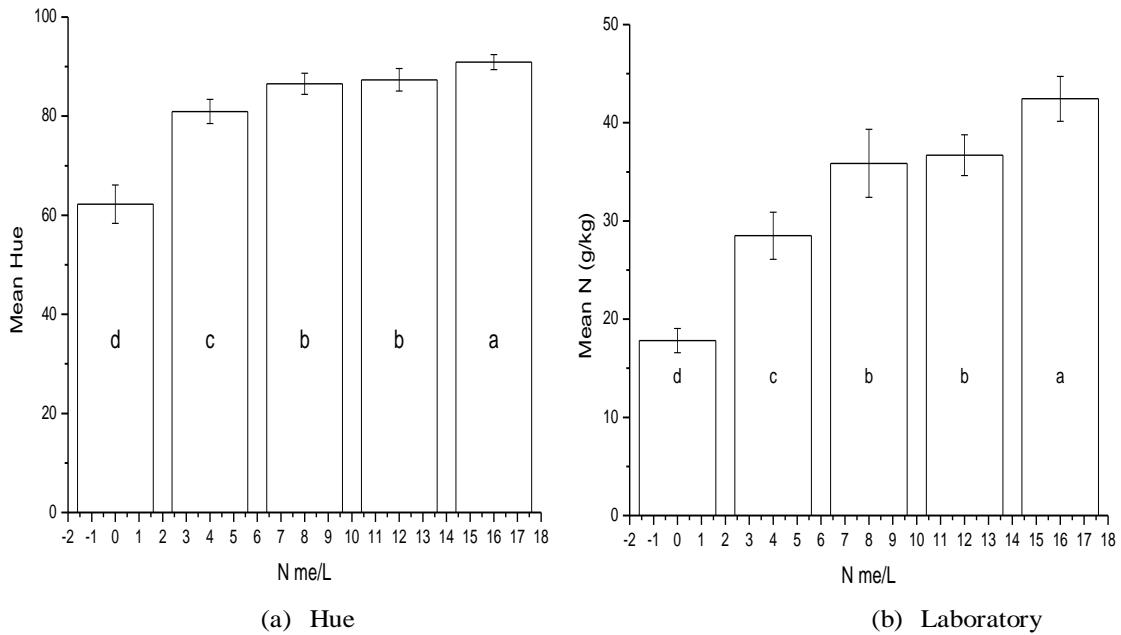


Figure 5. N levels estimated by (a) hue component values and (b) laboratory values ($p < 0.01$).

its components. Three values based on histograms and one in hue-saturation fusion were considered.

N estimation

Hue average

The range of hue values obtained in the five treatments was between fifty and ninety, values corresponding to green color. The correlation between this values and laboratory values was $R^2 = 0.86$ by a linear model (Figure

4).

One-way analysis of variance (ANOVA) was made for values from laboratory and others from hue values. The two ANOVAs were similar and can be seen that treatments N: 8 and 12 have no significance difference in both ANOVAs (Figure 5).

Luminance, saturation average and fusion saturation-hue

For these components we did not have favorable results.

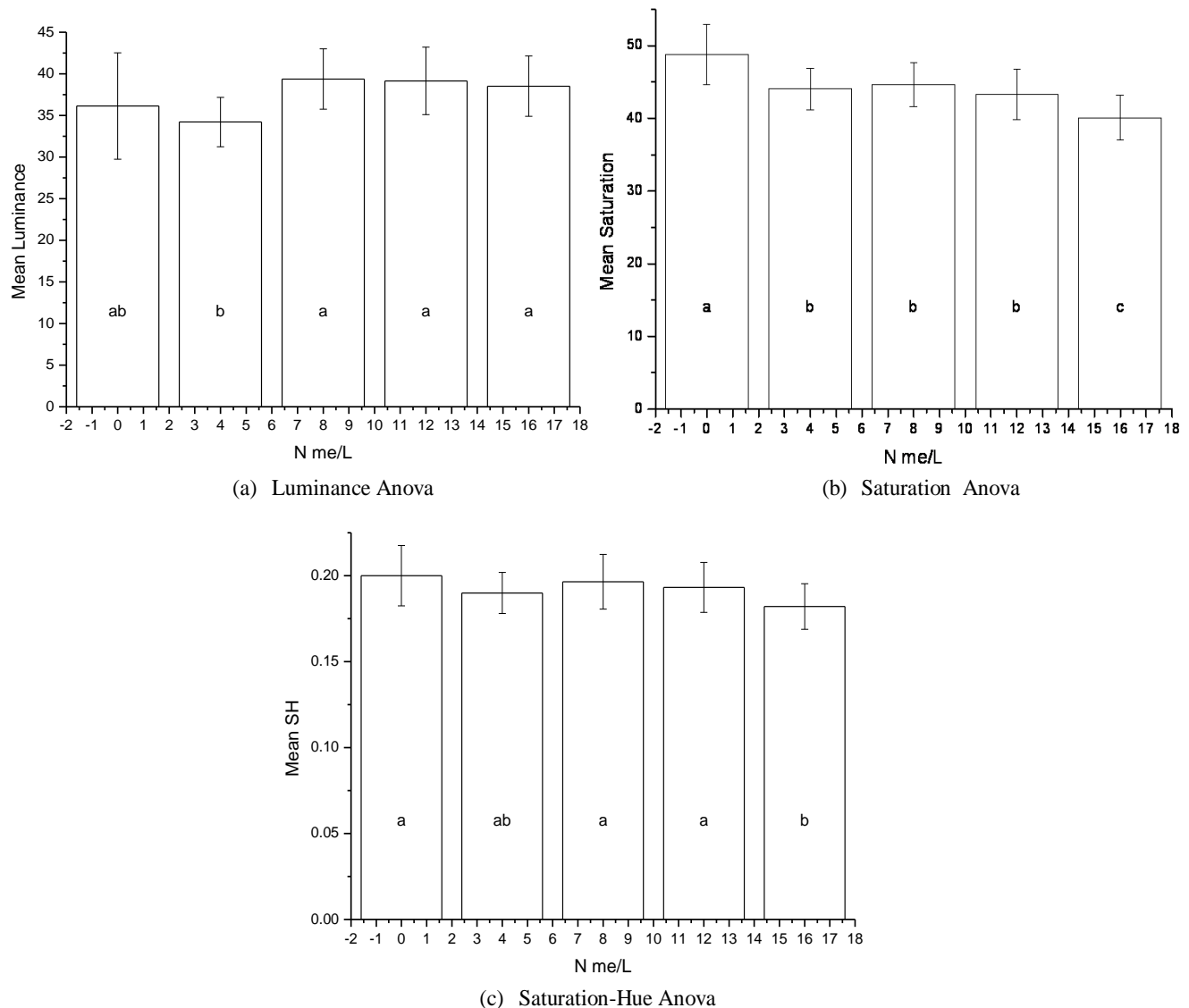


Figure 6. N levels estimated by (a) luminance, (b) saturation and (c) saturation-hue ($p < 0.01$).

Though we found significant differences among treatments (Figure 6a, b and c), the correlation for these methods were not satisfactory: luminance $R^2 = 0.65$, saturation $R^2 = 0.18$ and saturation-hue $R^2 = 0.29$. These components are not suitable for N estimation.

DISCUSSION

The result of this study was similar to Mercado-Luna (2010). He found that the red component in color space RGB has $R^2 = 0.82$. This result match with the result obtained in hue component. Though these values are in the range of green color (green = 120 ± 60), where there is lower green range the more the N deficiencies. From the correlations found in this work the hue is approximately

0.4% higher than the one found by Mercado-Luna (2010). Other study made by Pagola et al. (2009) in the measuring of N in barley found that using RGB color space in obtaining the greenness index and measurements obtained with a SPAD-502 chlorophyll meter were equal to or better than that of SPAD measurements. However, these studies used RGB color space and it is very susceptible to light changes. Other 3D-polar coordinate color spaces commonly used (HSV, HLS) are not suitable for quantitative image analysis (Hanbury and Serra, 2003). In IHLS, hue is the component that has color information; as in this study it was the better component to relate the N content.

Some of the advantages of the method are: easy to implement, inexpensive, fast measurements and the hue seems to be independent of the light intensity.

Conclusion

Based on the results from this work we concluded that it is feasible to estimate N deficiencies using IHLS color space in tomato seedlings where hue component has the better information. Hue-saturation, saturation and luminance did not show good correlation with N content.

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