

CHARACTERIZATION OF SOME AROMATIC AND MEDICINAL PLANTS SPECIES BASED ON UAV IMAGES

Ciprian BUZNA¹, Marinel Nicolae HORABLAGA^{1,2}, Luana SABO¹, Andreea Lidia JURJESCU¹,
Florin SALA^{1,2,*}

¹Agricultural Research and Development Station Lovrin, Lovrin, 307250, Romania

²University of Life Sciences "King Mihai I" from Timisoara, Timisoara, Calea Aradului, 300645, Romania

*Corresponding author: florin_sala@usvt.ro

Abstract. The study used imaging analysis to characterize several species of aromatic and medicinal plants. UAV images were taken on five aromatic and medicinal plants species, cultivated by SCDA Lovrin, Timis county, Romania. The biological material was represented by *Lavandula x intermedia* (Lavandin), P1; *Hyssopus officinalis* L., P2, P6; *Origanum vulgare* L., P3; *Thymus serpyllum* L., P4; *Salvia officinalis* L., P5 (P1 to P6 species code in the article). The images were analyzed (four repetitions) and the values of the RGB color parameters were obtained. The ANOVA test confirmed the presence of variance and the safety of the data ($F > F_{crit}$, $p < 0.001$; $\alpha = 0.001$). The correlation analysis highlighted positive and negative correlations of different intensity levels between RGB parameters and calculated ratios (R/G, R/B, G/R, G/B, B/R, B/G). The variation of G in relation to R was described by a polynomial equation of degree 3 ($R^2 = 0.956$), and the variation of B in relation to R was described by a polynomial equation of degree 2 ($R^2 = 0.736$). High variability was recorded in the case of parameter B ($CVB = 23.44534$), plant P3 (*Origanum vulgare* L.), and low variability was recorded in the case of color parameter G ($CVG = 2.66030$), plant P2 (*Hyssopus officinalis* L.). Based on PCA, the distribution diagram of plant species in relation to RGB color parameters and calculated ratios, as biplot, was obtained. PC1 explained 66.037% of variance, and PC2 explained 33.095% of variance in relation to RGB, and PC1 explained 58.923% of variance, and PC2 explained 36.46% of variance in relation to the calculated ratios. The cluster analysis facilitated the grouping of plant species (P1 to P6) based on similarity in relation to the RGB color parameter values (Coph.corr. = 0.959).

Keywords: aromatic plants, correlations, medicinal plants, models, PCA, UAV images

INTRODUCTION

Aromatic and medicinal plants have been known since ancient times, and they are used for the active principles in the treatment of diseases, in food, or in obtaining pharmaceutical and cosmetic products (Samarth et al., 2017; Salmerón-Manzano et al., 2020; Olas, 2022).

Numerous species in the category of aromatic and medicinal plants, are found in the spontaneous flora, or in different crops systems (Phondani et al., 2016; Bhattacharjee et al., 2020; González-Ball et al., 2022).

The aromatic and medicinal plants include numerous plants species, from the spontaneous flora as well as cultivated ones (Brinckmann et al., 2022)

Some studies have analyzed different connections between the biological and therapeutic properties of medicinal plants and certain cultivation practices (Chen et al., 2016; Chrysargyris et al., 2022).

The market of aromatic and medicinal plants was analyzed and studied based on the importance, economic value and potential of aromatic and medicinal plants worldwide, in relation to ecological, economic and social aspects (eg. social integration, maintaining labor force balances, processing and marketing, as well as research aspects) (Tanko et al., 2005; Ravi and Bharadvaja, 2019; Fitzgerald et al., 2020; Salmerón-Manzano et al., 2020; Taghouti et al., 2022).

Different species of medicinal plants have been studied in the specifics of agricultural research, from the perspectives of sustainability and multifunctionality (Licata et al., 2022).

The influence of soil conditions, climate, some pathogens, or stress factors was evaluated in relation to the production and level of active principles in numerous aromatic and medicinal plants (Misra et al., 2019; Thakur and Kumar, 2021; Hazrati et al., 2022).

Techniques based on imaging analysis (remote sensing, UAV) were used to analyze, characterize and discriminate some species of medicinal plants, in relation to temporal and spatial variability, or plant health (Kumar, 2010; Kandpal et al., 2021; Hamdane et al., 2022; Ding et al., 2023).

Techniques based on remote sensing were used in the study of medicinal plant resources, from the spontaneous flora or in cultivated areas, the identification of some species of medicinal plants, and the characterization of the variability of some habitats (Nimasow et al., 2016; Piri et al., 2019; Popescu et al., 2020; Guo et al., 2021).

Based on ground survey and remote sensing and GIS techniques, Saadi et al. (2020) evaluated the degree of land cover, the location of a medicinal plant species and modeled on spatial and non-spatial data the

relationship between over 184 plant species and land use.

Biodiversity monitoring, including species of medicinal plants in natural areas, was done based on remote sensing (Sentinel-2A), techniques that facilitated the identification of areas with high biodiversity, including those with a high risk of biological invasion (Liccari et al., 2022).

The purpose of this study was the analysis and characterization of some aromatic and medicinal plants species based on aerial images (UAV images), the analysis of some variation models and the evaluation of the level of similarity in relation to the values of the RGB color parameters and calculated ratios, resulting from the imaging analysis.

MATERIAL AND METHODS

Aromatic and medicinal plants from the SCDA Lovrin collection were analyzed.

The medicinal and aromatic plants considered in study were: Lavandin (*Lavandula x intermedia*), P1; *Hyssopus officinalis* L., P2, P6; *Origanum vulgare* L., P3; *Thymus serpyllum* L., P4; *Salvia officinalis* L., P5 (P1 to P6 species code in the article). In the field of collection and culture, the plants were in the form of bushes of variable size, depending on the vigor of each one (aromatic and medicinal plant bush). The images were taken with the drone (UAV, DJI Phantom 4), in the summer season (June 2020), figure 1.

For the unitary analysis, equal areas were selected from the image, for each plant species, on which the imaging analysis was done to obtain the RGB values (Rasband, 1997). Determinations were made in four repetitions within each plant species considered in the study. Ratios of proportionality between RGB parameters were calculated.



Lavandin (Lavandula x intermedia) P1 *Hyssopus officinalis* L. P2 *Origanum vulgare* L. P3 *Thymus serpyllum* L. P4 *Salvia officinalis* L. P5 *Hyssopus officinalis* L. P6

Figure 1. Aromatic and medicinal plants considered in the study (P1 to P6 – experimental code) (original image)

The series of RGB values and the calculated ratios were analyzed to evaluate the reliability of the data and the presence of variance.

PCA analysis and cluster analysis were used to obtain the distribution of variants (P1 to P6) in relation to RGB parameters and calculated ratios (R/G, R/B, G/R, G/B, B/R, B/G).

The calculation module from EXCEL and dedicated programs (Hammer et al. 2001; JASP, 2022) were used for the analysis and statistical processing of the recorded data and the generation of diagrams.

The calculation module in EXCEL and dedicated software (Hammer et al., 2001; JASP, 2022) were used for data processing and analysis.

RESULTS AND DISCUSSIONS

Digital UAV images were analyzed to obtain RGB spectral information for each plant species studied. The data series resulted, with minimum and maximum variation intervals (Min – Max) and standard errors (SE) presented in table 1. Depending on the specifics of each plant species, in relation to light in the visible spectrum, small values of the RGB parameters were recorded at P2 (*Hyssopus officinalis* L.) and high values at P3 (*Origanum vulgare* L.).

The values for the color parameter R varied between 38.55 ± 1.16 (plant P2 - *Hyssopus officinalis* L.) and 177.15 ± 3.70 (plant P3 - *Origanum vulgare* L.). In the case of the color parameter G, the values obtained from the analysis of the images varied between 77.77 ± 1.79 (plant P1) and 183.15 ± 4.62 (plant P3 - *Origanum vulgare* L.). In the case of the color parameter B, the values resulting from the analysis of the images varied between

4.51±0.60 (plant P3 - *Origanum vulgare* L.) and 113.74±3.10 (plant P4 - *Thymus serpyllum* L.).

The data series for the RGB parameters presented a normal distribution, according to the probability plot (figure 2) and of the values of the coefficients r ; $r=0.901$ for the R parameter; $r=0.893$ for the G parameter; $r=0.949$ for parameter B. The ANOVA test, single factor, confirmed the presence of variance in the set of recorded data, as well as the safety of the data, table 2.

Table 1. Values of the RGB parameters for the characterization of the plant species considered in the study

P	Range	R	G	B
P1	Min	49.12	77.77	52.54
	Max	57.08	88.20	64.97
	SE	±1.38	±1.79	±2.28
P2	Min	38.55	78.27	13.33
	Max	45.14	83.43	21.83
	SE	±1.16	±0.96	±1.49
P3	Min	157.20	155.59	4.51
	Max	177.15	183.15	7.93
	SE	±3.70	±4.62	±0.60
P4	Min	111.72	104.23	98.24
	Max	121.06	112.36	113.74
	SE	±1.76	±1.29	±3.10
P5	Min	59.89	97.26	59.61
	Max	68.00	107.29	73.40
	SE	±1.33	±1.78	±2.39
P6	Min	47.15	86.73	14.79
	Max	60.39	101.51	18.03
	SE	±2.27	±2.51	±0.65

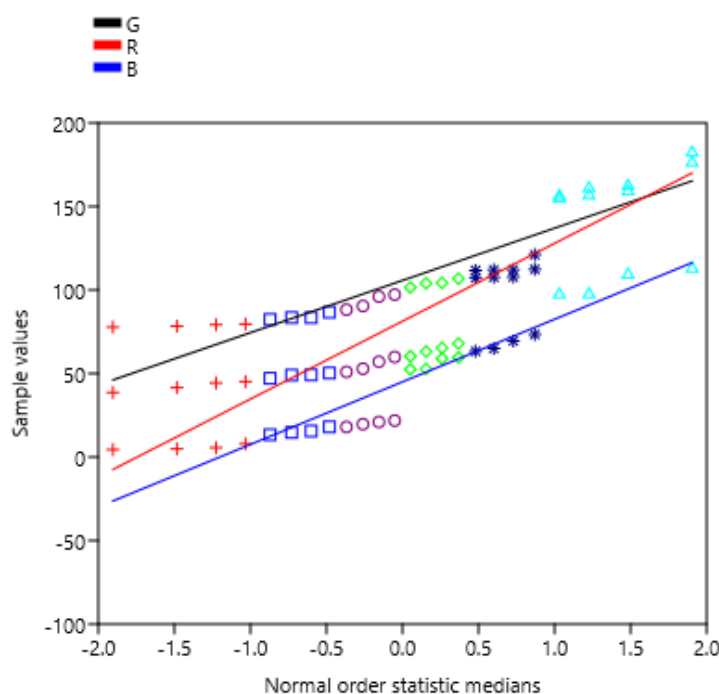


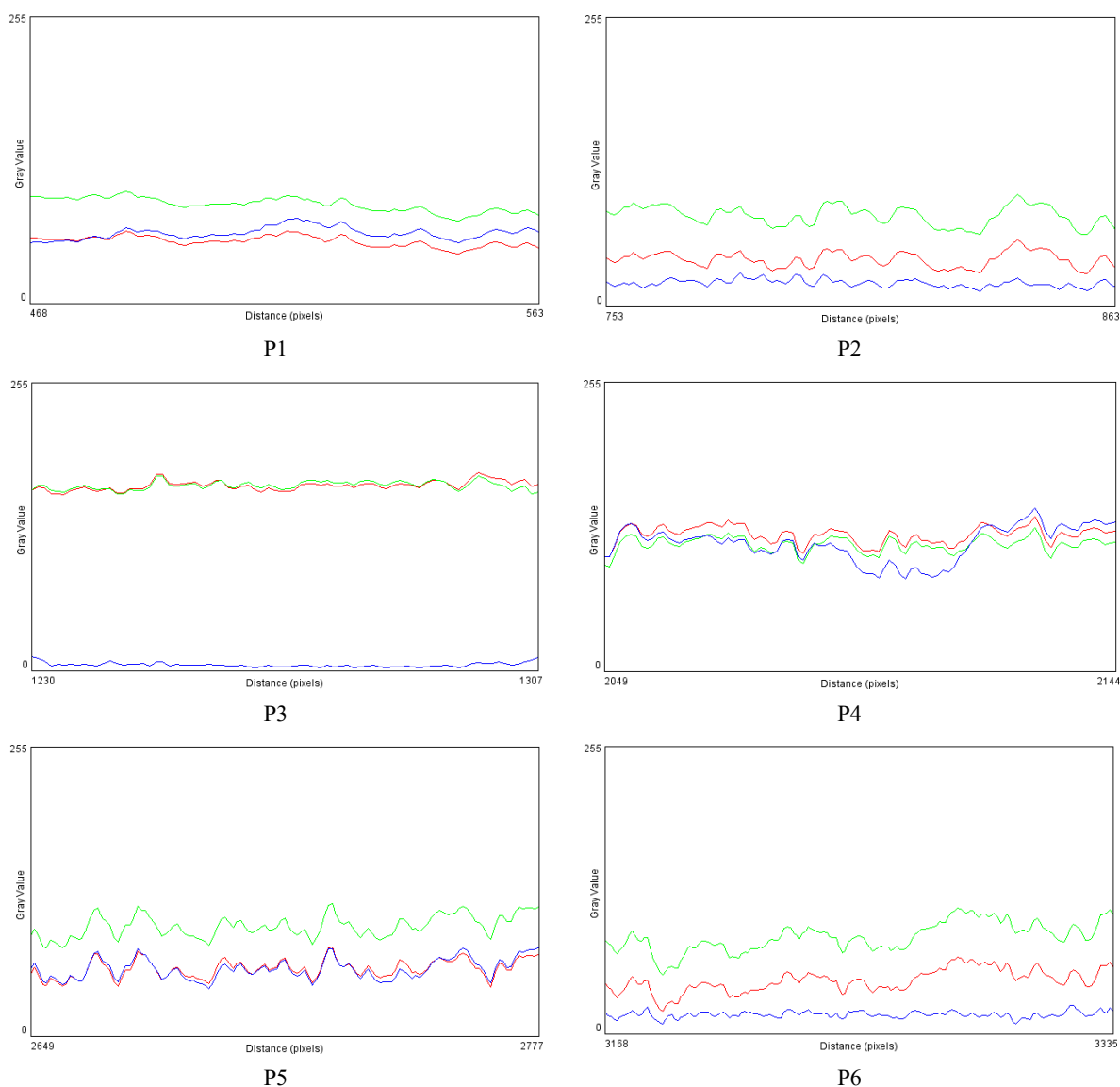
Figure 2. Normal probability plot for RGB parameters in the characterization of the plant species considered in the study

Table 2. ANOVA test

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	56015.04	2	28007.52	20.45597	5.23E-08	7.48645
Within Groups	119117.1	87	1369.161			
Total	175132.1	89				

Alpha=0.001

The RGB profile for each species of aromatic and medicinal plants studied was analyzed and is represented graphically in figure 3. From the analysis of the spectra, similarity was found in the case of plants P2 and P6 (*Hyssopus officinalis* L.), and distinct profiles in the case of the other plants species.

**Figure 3.** RGB spectra for the plants species studied

Based on the obtained values, the ratios between the RGB parameters were calculated for each plant species studied, and the correlation analysis was performed on the data series. Variable values of the correlation coefficient resulted, which indicated different levels of correlation under statistical safety conditions, table 3.

Different relationships of interdependence between RGB parameters were found. The variation of the G parameter in relation to R was described by equation (1), under conditions of $R^2=0.956$, $p<0.001$, with graphic

representation in figure 4 (a), and the variation of the G parameter in relation to R was described by equation (2), under conditions of $R^2=0.736$, $p<0.001$.

From the graphic analysis, figure 4 (a), it was found the grouped positioning of samples P1, P2, P5 and P6 (at the base of the variation curve) and the separate positioning of samples P4 (in the middle of the curve) and P3 (in the end area of the graphics curve). Similar results were recorded in the case of the variation of the parameter B in relation to R, equation (2), figure 4 (b).

$$G = 0.0001145 \cdot R^3 - 0.0321 \cdot R^2 + 3.225 \cdot R - 7.074 \quad (1)$$

$$B = -0.0224 \cdot R^2 + 4.58 \cdot R - 136.7 \quad (2)$$

Table 3. Correlation table between RGB parameters and calculated ratios

Variable		R	G	B	R/G	R/B	G/R	G/B	B/R	B/G
R	Pearson's r	—								
	p-value	—								
G	Pearson's r	0.939***	—							
	p-value	< .001	—							
B	Pearson's r	-0.01	-0.251	—						
	p-value	0.963	0.236	—						
R/G	Pearson's r	0.895***	0.695***	0.373	—					
	p-value	< .001	< .001	0.073	—					
R/B	Pearson's r	0.803***	0.907***	-0.540**	0.484*	—				
	p-value	< .001	< .001	0.006	0.017	—				
G/R	Pearson's r	-0.900***	-0.717***	-0.386	-0.989***	-0.498*	—			
	p-value	< .001	< .001	0.063	< .001	0.013	—			
G/B	Pearson's r	0.760***	0.881***	-0.601**	0.423*	0.996***	-0.432*	—		
	p-value	< .001	< .001	0.002	0.04	< .001	0.035	—		
B/R	Pearson's r	-0.418*	-0.552**	0.827***	-0.111	-0.709***	0.057	-0.756***	—	
	p-value	0.042	0.005	< .001	0.606	< .001	0.793	< .001	—	
B/G	Pearson's r	-0.124	-0.365	0.982***	0.267	-0.605**	-0.289	-0.664***	0.899***	—
	p-value	0.562	0.08	< .001	0.207	0.002	0.171	< .001	< .001	—

* $p < .05$, ** $p < .01$, *** $p < .001$

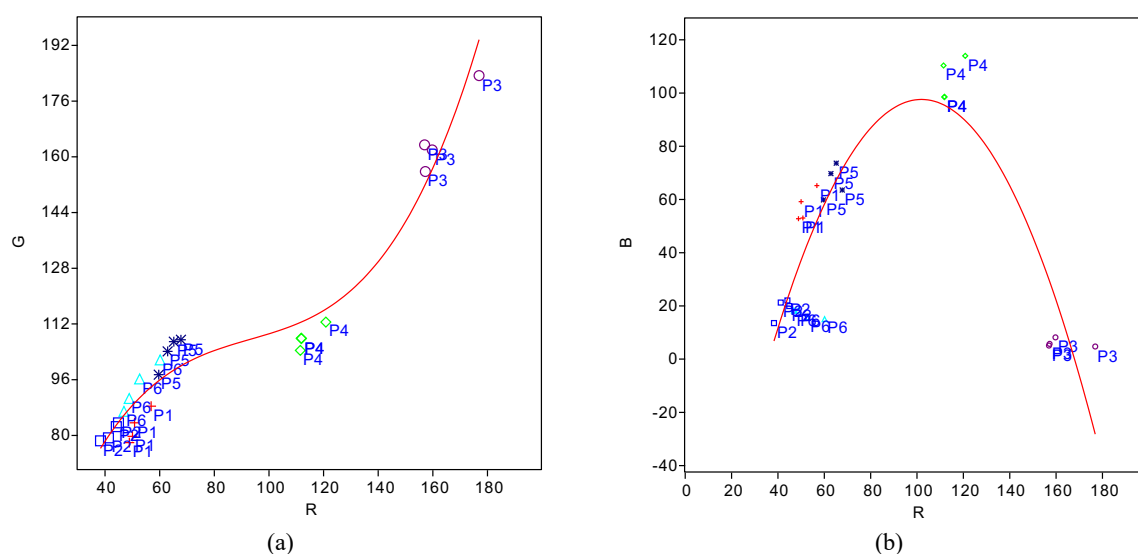


Figure 4. The variation of the G and B parameters values in relation to R parameter, in the description of the studied plant species

The variability in the RGB data series was evaluated based on the coefficient of variation (CV). From the analysis of the resulting values, a differentiated variability was found within the RGB color parameters. The highest value of the coefficient of variation was recorded in the case of the B color parameter at the plant P3, $CV_B=23.44534$, and the lowest value of the coefficient of variation in the case of the G color parameter, at the plant P2, $CV_G=2.66030$.

Within the color parameter R, a high value of the coefficient of variation was recorded at plant P6, $CV_R=9.67938$, and a low value was recorded at plant P4, $CV_R=3.45315$. In the case of the color parameter G, a high value of the coefficient of variation was recorded at plant P3, $CV_G=6.23101$, and a low value was recorded at plant P2, $CV_G=2.66030$. In the case of the color parameter B, a high value of the coefficient of variation was recorded at plant P3, $CV_B=23.44534$, and a low value was recorded at plant P4, $CV_B=6.0265$. Diversity profile, figure 5, graphically represents the variability recorded within the aromatic and medicinal plant species, based on the values of the recorded RGB parameters.

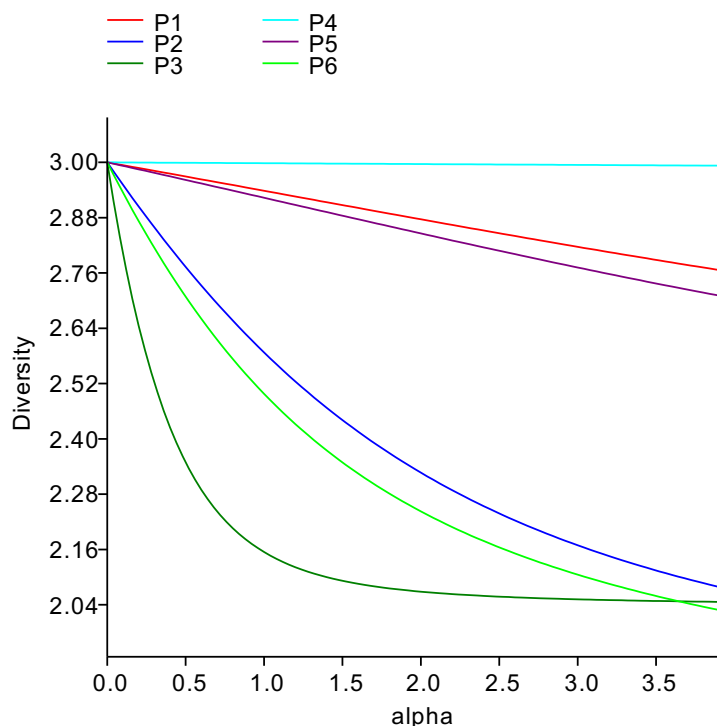


Figure 5. Diversity profile within the plant species studied, in relation to the RGB values

The PCA analysis led to the diagram in figure 6, in which the studied plant species (P1 to P6) were positioned differently in relation to RGB color parameters, as biplot. PC1 exploited 66.037% of variance, and PC2 explained 33.095% of variance. It was found the association of P4 with the color parameter B, the association of P3 with the color parameter G, the close positioning of P5 to B, followed by P1. P2 and P6 (*Hyssopus officinalis* L.) were positioned independently of RGB color parameters.

The PCA analysis based on the calculated ratios between the RGB values, led to the distribution of the species of aromatic and medicinal plants studied according to the diagram in figure 5. PC1 explained 58.923% of variance, and PC2 explained 36.46% of variance, figure 7.

The association of the P3 species with the R/B and G/B ratios was found; the association of P2 and P6 species with the G/R ratio; the association of species P1 and P5 with the B/R ratio; the association of the P4 species with the R/G and B/G ratios. The average values calculated for the ratios of the color parameters are shown in table 4, and the graphic distribution of the plant species studied based on the ratios calculated, average values, is presented in figure 8.

The cluster analysis facilitated the grouping of plants studied (P1 to P6) based on similarity in relation to the values of the RGB color parameters, the dendrogram in figure 9 (Coph.corr. = 0.959). The independent position was occupied by the plant P3 (*Origanum vulgare* L.). A high level of similarity was recorded between P2 and P6 (*Hyssopus officinalis* L.), SDI=16.488. The SDI values for all studied plants are presented in table 5.

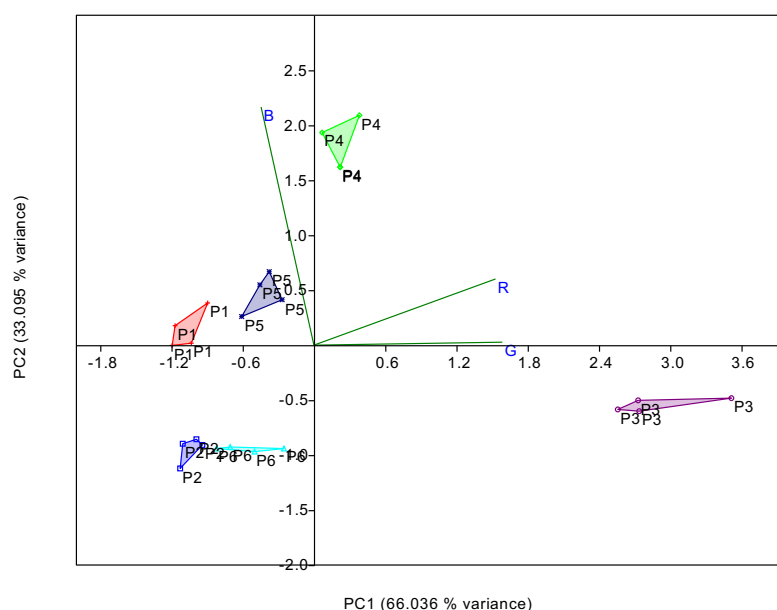


Figure 6. PCA diagram, with the distribution of the studied plants, in relation to RGB parameters

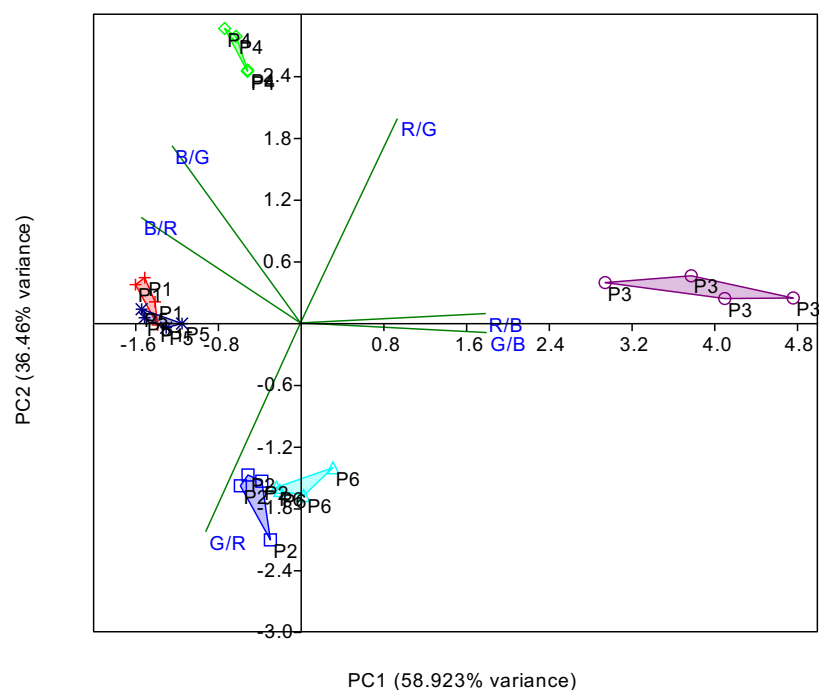


Figure 7. PCA diagram regarding the distribution of studied plant species based on the ratios calculated between RGB color parameters

Table 4. Average values calculated for RGB parameters in relation to the plant species studied

Experimental code	R/G	R/B	G/R	G/B	B/R	B/G
P1	0.631	0.905	1.586	1.435	1.105	0.697
P2	0.524	2.234	1.907	4.260	0.448	0.235
P3	0.982	28.601	1.018	29.126	0.035	0.034
P4	1.058	1.087	0.945	1.027	0.920	0.973
P5	0.618	0.965	1.619	1.562	1.037	0.640
P6	0.559	3.158	1.789	5.649	0.317	0.177

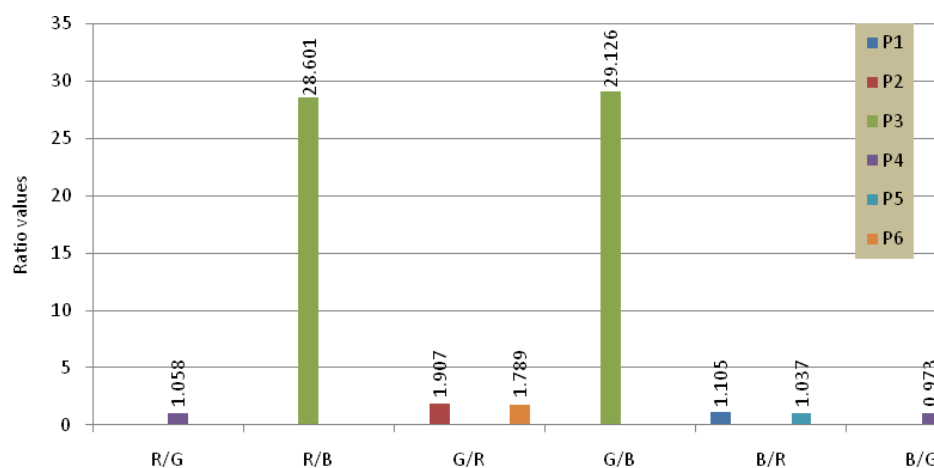


Figure 8. Graphic distribution of the significant RGB ratio values, depending on the plant species studied

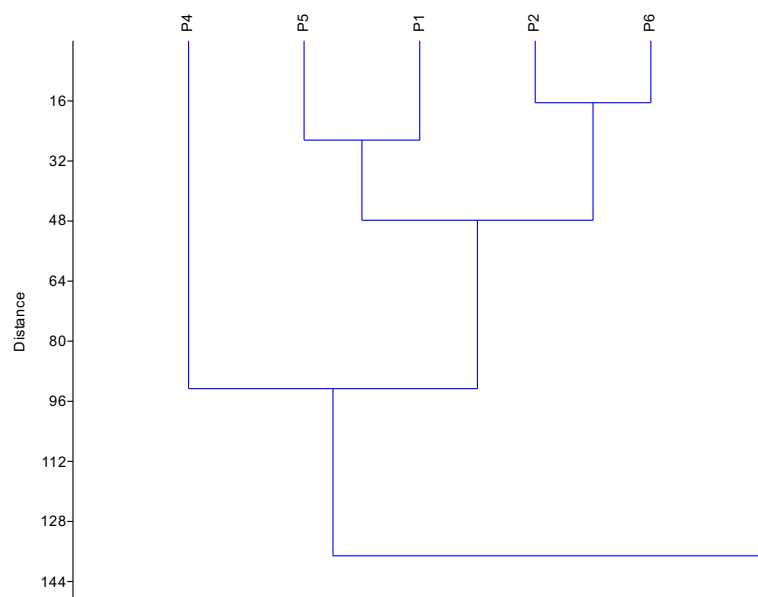


Figure 9. Dendrogram grouping the studied plants based on Euclidean distances

Table 5. SDI values for the studied plant species based on RGB values

Experimental code	P1	P2	P3	P4	P5	P6
P1		39.526	148.360	82.684	26.435	42.309
P2	39.526		148.220	115.430	57.078	16.488
P3	148.360	148.220		124.970	131.620	132.560
P4	82.684	115.430	124.970		63.430	108.940
P5	26.435	57.078	131.620	63.430		52.235
P6	42.309	16.488	132.560	108.940	52.235	

Imaging analysis studies have facilitated the comparative analysis, characterization, detection and classification of some plant species in relation to stress diseases (Lowe et al., 2017; Cheshkova, 2022), some apple varieties (Sala et al., 2017), of some genotypes in cultivated grasses (Constantinescu et al., 2018). In the case of medicinal plants, favorable results were reported in various studies regarding the analysis and classification of some species under statistical safety conditions (Kan et al., 2017; Putri et al., 2021; Azadnia et

al., 2022; Oppong et al., 2022).

In the context of the present study, RGB color parameters and some calculated ratios were identified as elements that were associated with the species of aromatic and medicinal plants studied, and can be considered as useful elements in the analysis and identification of these species in vegetation stages.

CONCLUSIONS

Imaging analysis based on UAV aerial images facilitated obtaining RGB spectral information useful in the characterization and classification of the considered aromatic and medicinal plant species.

Between the RGB values and the calculated ratios, positive and negative correlations were found, with variable levels of intensity, under statistical safety conditions ($p < .05$).

The variation of the color parameters G and B in relation to R was described by polynomial equations of degree 2 and 3. High variability was recorded in the case of parameter B at plant P3, $CV_B=23.44534$, and the lowest value of the coefficient of variation in the case of the color parameter G, at plant P2, $CV_G=2.66030$.

The PCA analysis facilitated the differentiated distribution of the plant samples (P1 to P6) in relation to the RGB values and the calculated ratios. A more reliable explanation was obtained under the conditions of using the values of the calculated ratios within the PCA, according to which PC1 explained 58.923% of variance, and PC2 explained 36.46% of variance. The association of the P3 species with the R/B and G/B ratios was found; the association of P2 and P6 plants with the G/R ratio; the association of P1 and P5 plants with the B/R ratio; the association of the P4 plant with the R/G and B/G ratios.

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