ANALYSIS OF SOME DEFICIENCIES IN CROPS OF WHEAT AND BARLEY BASED ON TERRESTRIAL AND AERIAL IMAGES

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Abstract. In this study were characterized various aspects of the plants lodging and weeds of wheat and barley as compared with the normal state, through image analysis. Observations were made in stages BBCH 73 Development of fruit and BBCH 93 – Senescence at wheat crops, respectively BBCH 87 (Ripening) and BBCH 93 (Senescence) at barley crops. From the analysis of the terrestrial and aerial images (drone DJI Phantom series) spectral data were obtained in the RGB system, based on which were calculated normalized values (rgb). The data obtained were analyzed in two ways in relation to the studied aspects: plants lodging (6 variants – V_1 to V_6) and weeds (8 variants – V_7 to V_{14}). With respect to the lodging of wheat and barley plants, the cluster analysis method facilitated the grouping of the data into two clusters, CI_L and CII_L, statistical safe, Cophenetic coefficient having the value of 0.774. The analysis has made the classification, both in relation to the two categories of crops (wheat and barley), as well as compared with the normal plants and lodging plants identified. In the situation of the second category of cases studied, was analyzed the presence of weeds in wheat and barley crops, compared to the normal status of the crops, in advanced stages of the growing season. The analysis grouped the 8 variants studied in two in clusters (CI_W - V_{12}, V_{13} and V_{14}; CII_W - V_7, V_8, V_9, V_{10}) and a independent position (V_{11}), in the average conditions of statistical certainty, the Cophenetic coefficient being 0.689. Regarding to the level of statistical certainty of results, it would have been higher if the analysis should have been done on each individual crop, but in the case of complex approach, the interaction of the phenomenon (plant lodging or weed, and crops), made that the safety level have lower values.

Keywords: *aerial images, barley, plant lodging, weeds, wheat*

INTRODUCTION

Wheat and barley plants have a proper growth and development in conditions of ensuring adequate water and nutrients, and protection against disease and pest control, and an appropriate culture technology. The anatomical structures of the stem in these species are a genetic trait, and in the most frequent conditions ensure the stability of the plants.

Adverse weather conditions such as wind, heavy rain, storms, have negative effects on wheat and barley crops, and these aspects have been studied in terms of fall of the plant, and the quantitative and qualitative impairment of the production (CLEUGH et al., 1998). Different formulas, models, and coefficients have been proposed and studied to describe certain forces that occur in the plant body under the influence of weather conditions, especially of wind influence (THOM, 1975; VOGEL, 1989; HOLLAND et al., 1991).

Characters of the wheat and barley plants that affect the lodging process, were studied on the basis of parameters of some specific models in order to assess the behavior of some biotypes and making recommendations for culture technologies, or for the plant breeding (BERRY et al., 2000, 2007). Various research programs reviewed lodging resistance of different cereals, especially in wheat (FOULKES et al., 2011).

BAKER et al. (1998) have developed a computational model for predicting the lodging risk of crops, in relation to the parameters of crops and soil.

Based on the model it was possible the correct prediction of 21 cultures fallen from the 30 studied, and 38 standing crops, of the 42 total studied. Another model of the lodging phenomenon has been adapted and tested at spring wheat under irrigation conditions in the North-West of Mexico (PINERA-CHAVEZ et al., 2016).

Although these, in some circumstances, occurred the phenomenon of the lodging of plants or crops, especially in the context of high doses of nitrogen and under conditions of strong wind, heavy rain or storms (CROOK and ENNOS, 1995; BAKER et al., 1998).

Monitoring of wheat and barley crops, based on terrestrial or aerial images, is already of interest, due to the facilities offered by the large area assessed, by the work speed, by the real time in which observations are made, and high precision (MURAKAMI et al., 2012; BENDIG et al., 2014; DU and NOGUCHI, 2017).

This study aimed at evaluating and classifying cases of lodging and weeds in crops of wheat and barley, through image analysis based on terrestrial and aerial images.

MATERIAL AND METHOD

The present study which followed the lodging phenomenon and weeds in crops of wheat and barley was carried out in the Didactic Station of USAMVB Timisoara in different plots where the cultures were placed. The studies were carried out during 2014 - 2016, depending on how those cases of interest were identified.

They were two crops studied: wheat crop, Alex and Ciprian cultivars, and barley crop Epoque, Saphira and Cardinal cultivars. In the case of wheat, was studied phenomenon of lodging on cultivar Alex, in the stage BBCH 73 - Development of fruit, and the phenomenon of weed on cultivar Ciprian, in the stage BBCH 93 - Senescence (MEIER, 2001). The phenomenon of the presence of the weeds was studied in barley culture, cultivar Cardinal, in the growing stage BBCH 87 (Ripening) and BBCH 93 (Senescence). Also, in barley has been studied the lodging phenomenon, cultivars Epoque and Saphira, in the Stage BBCH 93 (Senescence).

Image acquisition. Terrestrial images (Nikon D80), and aerial images (drone DJI Phantom series) were made on crops of wheat and barley, Figure 1.

The images were processed to obtain spectral information in RGB color channels, based on which were calculated through relations (1), (2) and (3) normalized values rgb (LEE and LEE, 2013). Image analysis was performed with ImageJ software (RASBAND, 1997).

$$r = \frac{R}{R+G+B} \quad (1)$$

$$g = \frac{G}{R+G+B} \quad (2)$$

$$b = \frac{B}{R+G+B} \quad (3)$$

Statistical analysis of experimental data. Experimental data were analyzed in terms of variance by the ANOVA test. To differentiate the cases with deficiencies as against to the normal cases, cluster analysis method was used. In the case of this analysis, based on Euclidean distances were made classifications and groupings for the cases studied (experimental variants). PCA analysis was used to evaluate the distribution of cases studied (experimental variants) compared to biplot (rgb). For the safety of the experimental data, were used specific parameters: Sample F, the parameter t, the Cophenetic coefficient. For the analysis of clusters

and PCA, has been used PAST software (HAMMER et al., 2001).

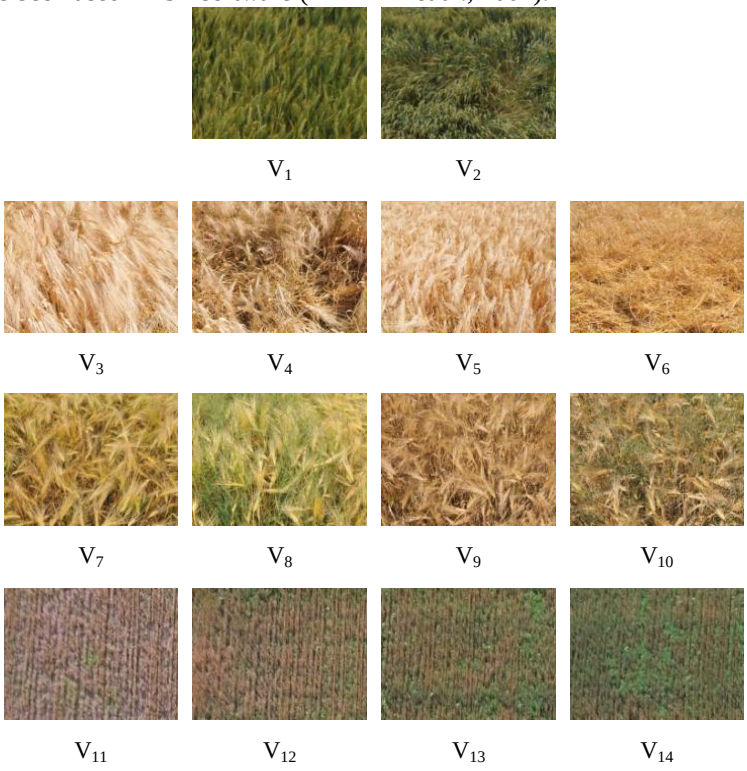

Figure 1. Images of wheat and barley crops studied.

V_1 - WCN_{BBCH73} - wheat crop normal ; V_2 - WCF_{BBCH73} – wheat crop lodging; V_3 - BCN – barley crop normal (Epoque cultivar); V_4 - BCF – barley crop lodging (Epoque cultivar); V_5 - BCN – barley crop normal (Saphira cultivar); V_6 - BCF – barley crop lodging (Saphira cultivar); V_7 - BC-$W_{BBCH-87}$ – barley crop without weeds in principal growth stage 8 – Ripening, BBCH code 87; V_8 - BC+$W_{BBCH-87}$ – barley crop with weeds; V_9 - BC-$W_{BBCH-93}$ – barley crop without weeds in principal growth stage 9 – Senescence, BBCH code 93; V_{10} - BC-$W_{BBCH-93}$ – barley crop with weeds; V_{11} - WC-$W_{BBCH-93}$ - wheat crop without weeds in principal growth stage 9 – Senescence, BBCH 93; V_{12} - V_{14} – WC+$W_{BBCH-93}$ - wheat crop with weeds: W_1 - reduced weeds density; W_2- medium weeds density; W_3 – high weeds density.

RESULTS AND DISCUSSIONS

Wheat and barley crops were assessed at different stages of growth, in relation to the deficient phenomenon studied. Therefore, digital images captured were analyzed to extract the RGB profile and obtain spectral values on the respective color channels.

The lodging phenomenon was analyzed on wheat, cultivar Alex, stage BBCH 73 (development of fruits). This phenomenon has been studied also on barley, cultivars Epoque and Saphira, in the stage 9 - Senescence (BBCH 93). The presence of weeds was analyzed in the stage 8 - Ripening (BBCH 87) on barley, cultivar Cardinal, and in the stage 9 - Senescence (BBCH 93) on barley (the same cultivar), and on wheat, cultivar Ciprian.

All identified cases were analyzed compared with the normal status of crops in the

same growing stages. The experimental data, in the form of numerical values in the RGB channels and the normalized values (rgb) are shown in Table 1.

Table 1

The values of RGB color chanel, and the rgb normalized values which describe the different cases deficient in crops of wheat and barley

Case study	Trial	R	G	B	r	g	B
WCN (Alex)	V_1	96.07±7.80*	96.27±6.76	41.92±3.63	0.4101	0.4110	0.1789
WCF (Alex)	V_2	92.90±4.81	93.27±4.74	53.97±3.42	0.3869	0.3884	0.2247
BCN (Epoque)	V_3	208.21±6.65	180.33±8.80	140.82±11.07	0.3933	0.3407	0.2660
BCF (Epoque)	V_4	161.46±15.73	132.53±15.82	91.24±13.65	0.4191	0.3440	0.2368
BCN (Saphira)	V_5	202.40±7.92	172.86±10.27	130.99±12.57	0.3998	0.3415	0.2587
BCF (Saphira)	V_6	185.03±3.69	148.81±3.92	90.66±3.75	0.4359	0.3506	0.2136
BC-$W_{BBCH-87}$ (Cardinal)	V_7	160.37±7.07	135.78±7.00	73.53±5.68	0.4338	0.3673	0.1989
BC+$W_{BBCH-87}$ (Cardinal)	V_8	162.88±12.48	152.23±8.57	85.06±6.09	0.4070	0.3804	0.2126
BC-$W_{BBCH-93}$ (Cardinal)	V_9	158.73±8.12	128.80±8.34	83.24±7.26	0.4281	0.3474	0.2245
BC+$W_{BBCH-93}$ (Cardinal)	V_{10}	146.41±7.07	127.84±6.51	82.35±5.72	0.4106	0.3585	0.2309
WC-$W_{BBCH-93}$ (Ciprian)	V_{11}	141.74±5.27	117.37±5.27	104.57±5.76	0.3897	0.3227	0.2875
WC+$W_{1\ BBCH-93}$ (Ciprian)	V_{12}	126.37±6.00	107.71±4.57	81.97±4.64	0.3998	0.3408	0.2594
WC+$W_{2\ BBCH-93}$ (Ciprian)	V_{13}	110.96±5.47	104.55±3.99	72.86±3.44	0.3848	0.3626	0.2527
WC+$W_{3\ BBCH-93}$ (Ciprian)	V_{14}	100.35±3.99	103.37±4.44	72.22±2.81	0.3637	0.3746	0.2617

WCN_{BBCH73} - wheat crop normal ; WCF_{BBCH73} – lodging in wheat crop; BCN – barley crop normal; BCF – lodging in barley crop; BC-$W_{BBCH-87}$ – barley crop without weeds in principal growth stage 8 – Ripening, BBCH code 87; BC+$W_{BBCH-87}$ – barley crop with weeds; BC-$W_{BBCH-93}$ – barley crop without weeds in principal growth stage 9 – Senescence, BBCH code 93; BC-$W_{BBCH-93}$ – barley crop with weeds; WC-$W_{BBCH-93}$ - wheat crop without weeds in principal growth stage 9 – Senescence, BBCH 93; WC+$W_{BBCH-93}$ - wheat crop with weeds: W_1 - reduced weeds density; W_2- medium weeds density; W_3 – high weeds density; *Standard Deviation (Std.Dev.).

The ANOVA test, under the conditions alpha = 0.001, has revealed the source of variance, in condition of safety of the results (F> F crit, p << 0.001), data being presented in Table 2.

Table 2

ANOVA test, single factor

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	330362.2	5	66072.45	138.6271	2.57E-37	4.59554
Within Groups	37176.37	78	476.6201			
Total	367538.6	83				

Alpha = 0.001

The overall analysis of the cases studied indicated that, in the situation of abnormalities of this two crops (lodging and weeds) were registered lower values for RGB, respectively for normalized values (rgb), as compared to the normal state.

In the wheat crop, on the case of lodging plants areas, the values for R and G were

lower compared to the situation of normal crop, while B values were higher. In the case of the same situation in barley crop cultivar Epoque (lodging of the plants), were registered lower RGB values compared with the normal status of the crop. Similar values were recorded and to the Saphira cultivar. In the case of the presence of weeds in the crop of barley, in both growing stage studied, the RGB values were lower compared to normal crop situation.

Cluster analysis of the RGB data, in the case of normal crop on wheat and barley, and in the case of lodging, yielded two distinct clusters CI_L and CII_L, Figure 2. The cluster CI_L included two wheat cases: normal culture (V_1) and culture affected by lodging (V_2). The Cluster CII_L had two subclusteres: $CII_L/1$ with the variants V_3 (Epoque cultivar) and V_5 (Saphira cultivar), which is the normal state in the two varieties and the subcluster $CII_L/2$, with the variants V_4 (Epoque cultivar) and V_6 (Saphira cultivar), which is the lodging state of crops. The classification based on Euclidean distances presented high statistical certainty, the Cophenetic coefficient being 0.774.

A similar analysis in crops of barley and wheat, with weeds and without weed, afforded the dendrogram of Figure 3. The two crops, although analyzed together, have been identified and grouped separately, resulting an independent position (V_{11} – normal wheat crop), and two subclusters. The subcluster CI_W containing variants: V_{12}, V_{13} and V_{14} with different degrees of weeds in wheat crop. The second subcluster, CII_W, includes variants with weeds (V_7 and V_9) and variants without weeds (V_8 and V_{10}) in barley crop. The classification of these cases studied, presence of weeds in crops of wheat and barley, had an average statistical certainty, Cophenetic coefficient having the value of 0.689.

Based on PCA the distribution of studied cases is shown in Figure 4, provided that the % of variance for PC1 is 72.722, and % of variance for PC2 is 27.278.

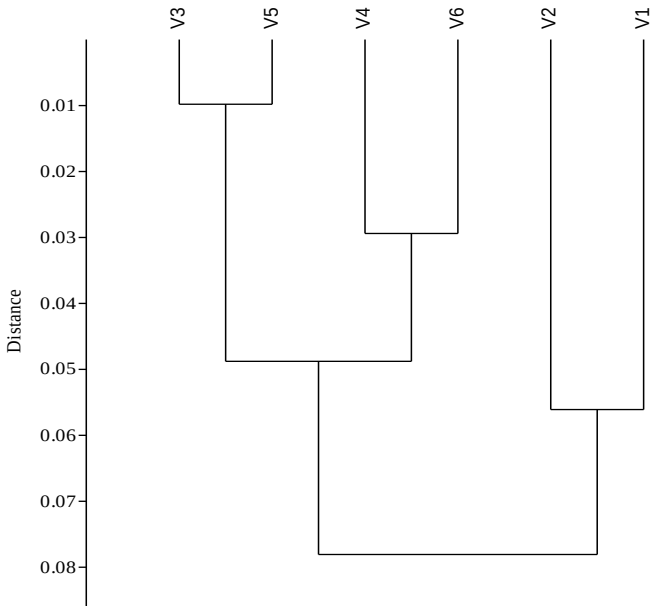

Figure 2. The clusters of the variants in relation to the normal state and lodging in wheat and barley crops, on the basis of Euclidean distances

Balanced fertilization of crops of wheat and barley provides physiological indices and normal operating parameters of the plants (RAWASHDEH AND SALA, 2013, 2016), with favorable effects on the production and quality (RAWASHDEH ET AL., 2014).

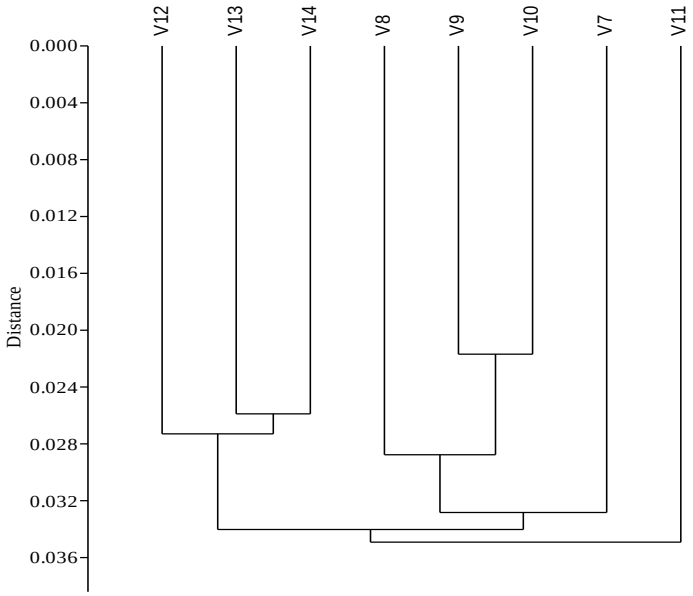

Figure 3. The clusters of variants in relation to the normal state of crops and weeds in wheat and barley, on the basis of Euclidean distances

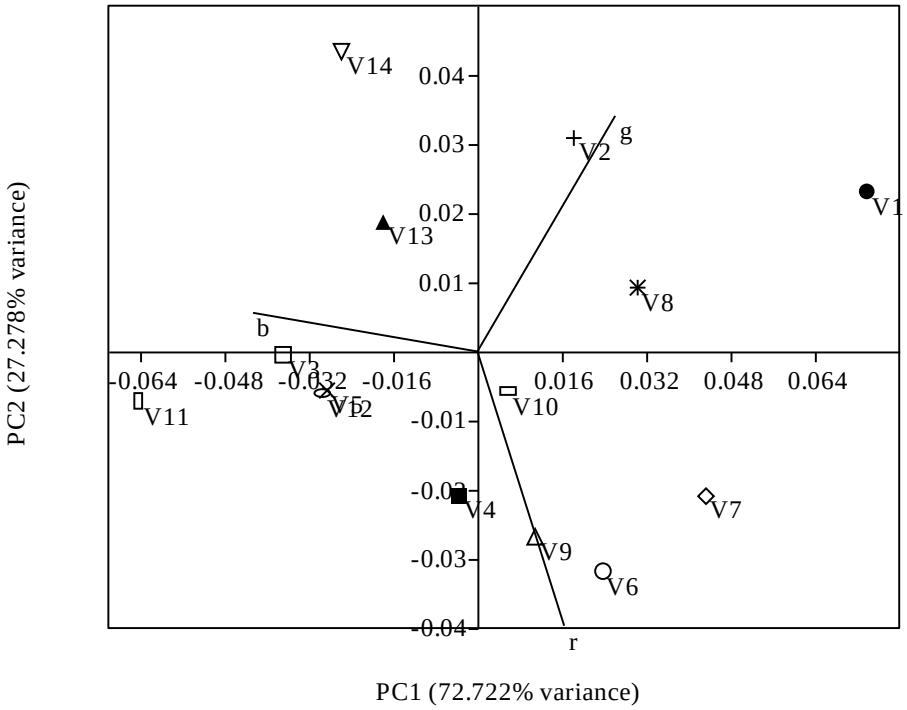

Figure 4. Principal Component Analysis; distribution of variants in relation to rgb biplot

Many models have been developed to optimize economic fertilization and agricultural technologies (BOLDEA and SALA, 2010; SALA and BOLDEA 2011), but equally important are models for estimating risks in crops such as lodging and weeds. Therefore, the monitoring of crops, in order to know in real time the status of their general and particularly in the two cases studied, is required. Imaging methods have advantages because of that are fast, accurate enough and facilitates real-time knowledge of the condition of crops (LELONG et al., 2008; BOCK et al., 2010; GOMEZ-CASERO et al., 2010; HERBEI and SALA, 2014, 2015). Dynamic analysis of the crop during the growing stages, and estimation of biomass on the basis of satellite and aerial images are current methods in the monitoring of agricultural crops (BENDIG et al., 2014; HERBEI and SALA, 2016). Aspects of the presence of weed and crop plant health, lodging of plants, and other specific phenomena are also analyzed by imaging techniques based on satellite aerial or terrestrial images (LABUS et al., 2010; YAND et al., 2015).

Through analysis digital terrestrial and aerial images, this study managed to differentiate the cases affected by the lodging and weeds in crops of wheat and barley.

CONCLUSIONS

The cases of lodging of the plant and the presence of weeds in crops of wheat and barley have been described separately on the basis of the spectrum RGB values and normalized values rgb, respectively. In all cases of deficiencies found, the lodging of the plants and presence of weeds, in wheat and barley crops, r and g values were lower and the value of g were higher compared to the normal cases. Cluster analysis, based on Euclidean distance, has clear detected safely statistical, the cases of lodging of the plant, and the presence of weeds in

wheat and barley crops, in the growing stages studied. These results support the possibility to achieving of an model to study of some deficiencies in crops based on spectral information (RGB, rgb) and statistical tools used.

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