RESEARCH ARTICLE

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Indirect Selection of Tolerant Barley (*Hordeum vulgare* L.) Genotypes under Semi Arid Conditions Based on the Numerical Images Analysis Indices

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ABSTRACT

Image analysis systems have been increasingly utilized for the assessment of plant growth and health for decades. We used in this study the software Mesurim Pro to evaluate the variation of the leaf reflectance at Red, Green and Blue and the variation of the senescence parameters. The analysis of variance revealed that the reflectance at different wavelengths (Red, Blue and Green) was highly significant genotypes effects (P < 0.001); for this parameter the good genotypes are those we have the lowest values such as G19. In addition, the preferable genotypes were those which have low values for the mean senescence and senescence velocity; based on this raison the best genotype was the introduce genotype G12. The genotypes effect was significant for the grain yield and thousand-kernel weight, for the chlorophyll content and the analysis of variance showed a significant effect of genotypes, the highest values registered by the introduced genotype G5 this one was in the same homogenize group of G2, G4, G8 and G18. The ranking of genotypes based on all parameters suggested that the genotypes G11, G12, G5, G15 and G18, respectively (introduce genotypes) were the ideal genotypes under these conditions.

Key words: Barley (*Hordeum vulgare* L.), Reflectance, Senescence, Selection, Semi-arid.

INTRODUCTION

Barley (*Hordeum vulgare* L.) is the one of the most important cereal grain crops is cultivated all over the world; after wheat, rice, corn and potato has the fifth rank in production point of view in world. Also, barley is the main food resource for human beings and livestock in Middle East. The adaptation of barley is better than wheat and other crops in environmental stresses condition; nevertheless, abiotic stresses are a major factor limiting barley production in many Mediterranean environments (Ceccarelli and Grando, 1996). Drought stress is a significant abiotic factor that can diminish photosynthesis efficiency by reducing leaf expansion, hence, causing premature leaf senescence. Senescence is defined as the gradual deterioration of its functions with age, as leaves change color because chlorophyll is broken down, water content is reduced and membranes break down (Hafsi and Guendouz, 2012). Pigments are integrally related to the physiological function of leaves. Chlorophylls absorb light energy and transfer it into the photosynthetic apparatus. Carotenoids (yellow pigments) can also contribute energy to the photosynthetic system. Changes in leaf reflectance of green leaves with maturation and senescence have been attributed to changes in chlorophyll and mesophyll arrangement (Grant, 1987).

Variations in leaf chlorophyll content detectable by Spectral reflectance have also been shown to be related to leaf development and senescence (Carter and Knapp, 2001). Canopy spectral reflectance provides an important method for plant canopy study under different environmental conditions. The visible region of the vegetation reflectance spectrum is characterized by low reflectance and transmittance due to strong absorptions by foliar pigments. For example, chlorophyll pigments absorb violet-blue and red light for photosynthesis. Green light is not absorbed for photosynthesis, hence most plants appear green. Recently, digital imagery has become a new trend in plant color analysis. Digital cameras or scanners in combination with computers and appropriate software can be used to photograph, scan and evaluate leaves for color with relative ease and at an affordable cost. In agriculture, digital technology has been used to characterize color in apples (Schrevens and Raeymaeckers, 1992), evaluate senescence rates in spring wheat (Adamsen *et al*., 1999) and durum wheat (Hafsi *et al*., 2000; Guendouz and Maamari, 2011; Guendouz *et al*., 2012). The aim of this study is to evaluate the efficiency of using the numerical image analysis indices to select tolerant and adapted genotypes under semi arid conditions.

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MATERIALS AND METHODS

Plant material and experiment designs

Set of 26 genotypes of barley (*Hordeum vulgare* L.) (Table 1) were planted on 17 December 2017, in the experimental fields of ITGC, Setif, Algeria (5°20′E, 36°8′N, 958m above sea level) genotypes were grown in randomized block design with three replicates. Plots were 5 m × 6 rows with 0.20 m row spacing and sowing density was adjusted to 250 g m^{-2}.

Flag leaf reflectance (FLR) and leaf senescence (S)

Flag leaf reflectance (FLR) and leaf senescence (S) was evaluated by numerical image analysis (NIA) according to Guendouz *et al*. (2012) and Hafsi *et al* (2000). To estimate the reflectance at Red, Green and Blue (RGB); leaves were photographed on black surface, between 11:00 and 12:00 solar time with a color digital camera (Canon, Power Shot A460, AiAF, CHINA). Images were stored in a JPEG (Joint Photographic Expert Group) prior to downloading onto a PC computer and analyzed using Mesurim Pro (Version 3.3) software (Fig 1). Senescence was expressed as the ratio of senesced area to total leaf area (in per cent). Measurements were carried out eight times between flowering and the end of senescence for each genotype. In addition to S, two parameters calculated to characterize the dynamics of senescence; average senescence (S %) was calculated as the mean of the S_1 to S_8 values. The velocity of senescence (S_v) was calculated for each date of senescence measurement as $(S_{i+1} – S_i) / (\Sigma_{ti+1} – \Sigma_{ti})$.

Chlorophyll content (Chl)

The SPAD-502 measures the amount of chlorophyll (Chl) in the leaf, which is related to leaf greenness, by transmitting light from light emitting diodes (LED) through a leaf at wavelengths of 650 and 940 nm. SPAD meters have been used to estimate chlorophyll concentrations and infer nitrogen status of single leaves of wheat, corn *(Zea mays* L.) and other plants (Wood *et al*., 1993; Blackmer and Schepers, 1995).

Agronomical measurements

Furthermore, grain yield (GY) and thousand-kernel weight (TKW) was determined from sub-samples taken from harvested grains of each plot.

Statistical analysis

Data were analyzed using Costat, version 6.4. The analysis of variance was performed for all agronomical and physiological traits and Fisher's LSD multiple range test was employed for the mean comparisons. Linear correlation

Table 1: Origin and spike type of the genotypes used in study.

Genotypic code	Origin	Spike type (Row)	Genotypic code	Origin	Spike type (Row)
G1	ICARDA	2	G14	ICARDA	2
G2	ICARDA	2	G15	ICARDA	2
G3	ICARDA	2	G16	ICARDA	2
G4	ICARDA	2	G17	ICARDA	2
G5	ICARDA	2	G18	ICARDA	2
G6	ICARDA	2	G19	ICARDA	2
G7	ICARDA	2	G20	ICARDA	2
G8	ICARDA	2	G21	ICARDA	2
G9	ICARDA	2	G22	ICARDA	2
G10	ICARDA	2	G 23- Fouarra	Algeria	6
G11	ICARDA	2	G 24- Saida183	Algeria	6
G12	ICARDA	2	G 25- Tichedrett	Algeria	6
G13	ICARDA	2	G 26- Rihane 03	Algeria	6

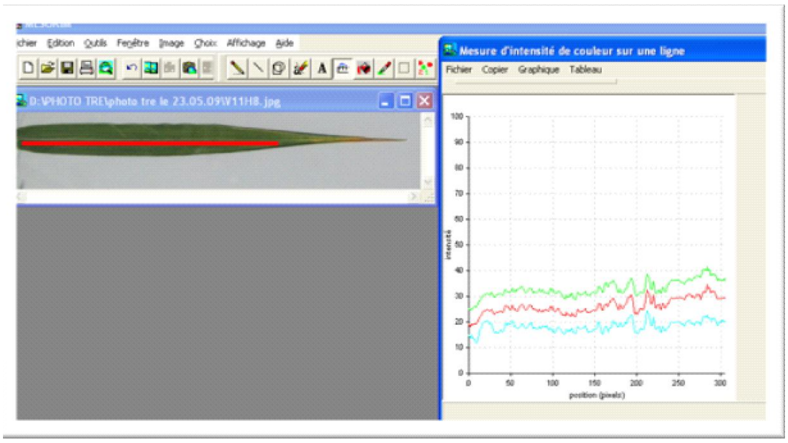

Fig 1: Description of measuring the reflectance at RGB (Red, Green, Blue) using Mesurim Pro software.

analysis was used to determine the relationships between the traits studied.

RESULTS AND DISCUSSION

Flag Leaf reflectance (FLR) and senescence (S)

In this study flag leaf reflectance was measured at Red (654 nm), Blue (450 nm) and Green (500 nm); as shown in Table 2, analysis of variance revealed that the reflectance at different wavelengths (Red, Blue and Green) was highly significant genotypes effects (P < 0.001). Reflectance at Red ranged from 29.98% for G19 to 45% for G1 with an average of 35.8 % over all genotypes; for this parameter the good genotypes are those we have the lowest values such as G19. The local genotypes have the highest values with a global mean of 37.84%. In addition, the mean of the reflectance at Blue in the introduce genotypes was 30.19 % and in the local genotypes was 30.02 % with a total mean of 30.22 %. The lowest value of the reflectance at Blue registered in the genotype G22 this one was in the same homogenize group of G11, G15 and the local genotype Saida 183 (G 24), there was no significant difference for the reflectance at Blue between the local and introduce genotypes. As shown in Table 2, the parameters of senescence there was significant difference between genotypes. The values of the mean senescence varied from 34.96 % for the introduce genotype G12 to 66.05 % for G 17 (introduce genotype) with total mean of 56.19 %. The analysis of variance based on the origin effects showed the

Table 2: Response of Reflectance, Senescence, chlorophyll content, GY and TKW of barley genotypes tested under semi-arid conditions.

Genotypes	Reflectance %			Senescence		Agronomic traits		
	Red %	Green %	Bleu %	S %	S_v	Chlorophyll	GY	TKW
G1	45	52,33	33,82	43,54	0,38	30,06	72,74	53
G2	37,11	47,48	30,97	53,2	0,56	44,49	66,06	46,2
G3	34,67	45,66	30,62	60,44	0,45	33,23	68,39	50,29
G4	37,93	49,13	31,74	60,51	0,55	41,66	54,09	46,74
G5	31,77	42,89	29,57	57,96	0,56	49,75	57,08	52,49
G6	35,1	46,63	31,31	60,6	0,55	37,9	56,85	46,65
G7	36,43	46,66	30,45	59,37	0,54	41,05	61,22	47,69
G8	36,55	46,16	30,72	54,46	0,55	35,11	56,56	46,13
G9	34,93	45,62	30,02	56,02	0,47	45,6	45,18	44,4
G10	37,19	47,76	31,19	55,12	0,48	33,73	50,35	47,42
G11	31,76	43,22	28,13	50,4	0,48	39,7	56,77	50,09
G12	36,19	46,87	30,14	34,96	0,32	36,1	70,53	57,26
G13	39,55	47,52	31,12	65,37	0,49	36,96	44,12	45,5
G14	39,59	50,37	30,63	57,37	0,56	36,1	52,9	49,42
G15	30,76	42,54	27,41	56,08	0,43	30,8	44,29	47,78
G16	35,98	46,27	29,42	66,03	0,46	35,94	51,36	48,49
G17	32,1	43,83	29,65	66,05	0,42	27,5	46,72	48,64
G18	32,8	44,55	30,59	53,72	0,48	41,55	58,71	46,09
G19	29,98	43,29	29,66	56,77	0,44	33,23	51,99	48,18
G20	35,6	47,59	29,91	57,96	0,52	40,31	43,09	45,36
G21	38,39	48,36	30,88	51,57	0,55	34,46	58,68	47,94
G22	30	42,26	27,71	58,72	0,53	32,63	50,12	49,01
G23 (Fouarra)	40,63	49,52	31,76	50,86	0,52	27,5	74,4	47,53
G24 (Saida 183)	39,72	49,37	27,68	53,57	0,44	34	52,36	55,91
G25 (Tichedrette)	36,49	47,12	29,48	55,19	0,47	32,18	57,44	49,89
G26 (Rihane 03)	34,51	47,19	31,15	65,14	0,7	32,77	43,99	41,01
Min	29,98	42,26	27,41	34,96	0,32	27,5	43,09	41,01
Max	45	52,33	33,82	66,05	0,7	49,75	74,4	57,26
Total Mean	35,8	46,55	30,22	56,19	0,5	36,32	55,62	48,43
Local genotypes Mean	37,84	48,30	30,02	56,19	0,53	31,61	57,05	48,59
Introduce genotypes Mean	35,43	46,23	30,19	56,19	0,49	37,18	55,35	48,40
Genotypes Effects	***	***	***	***	***	***	***	***
$LSD_{5\%}$	2,6	2,08	1,65	0,93	0,015	8,32	14,9	2,16
Origine Effects	*	*	ns	ns	ns	**	ns	ns
$LSD_{5\%}$	2.9	2.06	1.22	5.59	0.059	5.35	9.57	2.94

Sa % : average senescence, S_v: Senescence velocity.

absence of difference between the local and introduce genotypes for all senescence parameters. The preferable genotypes were those which have low values for the mean senescence and senescence velocity; based on this raison the best genotype was the introduced genotype G12. The data of the Table 3 demonstrate that the best genotypes were the genotype which in the top of the ranking list. Based on the indices of FLR and S the best genotypes were G22, G15, G11, G5, G19, G17 and G18, respectively. The total score of the genotypes based on the all parameters demonstrated that the best genotypes were G11, G12, G5, G15 and G18, respectively. Spectral reflectance measurements have been successfully used to estimate biomass, leaf area index, photosynthesis and/or yield in several species of trees (Richardson *et al*., 2001), bread wheat (Filella *et al*., 1995) and durum wheat (Aparicio *et al*., 2004). Ferrio *et al*. (2005) showed that the higher grain yield was correlated with lower reflectance are visible. The results of Guendouz *et al*. (2013) indicated the potential of using flag leaf reflectance wheat yield prediction.

GY, TKW and Chlorophyll content (Chl)

The genotypes effect was significant for the grain yield and thousand-kernel weight (Table 2). The values of grain yield varied between 43.09 q/ha for the introduce genotype G20 to 74.4 q/ha for the local landrace Fouarra. Based on the test of means comparison the genotypes with highest GY were G1, G2, G3, G7, G12 and local landrace Fouarra; in addition, the highest TKW was registered by the introduced genotype G12. The homogenize group of genotypes which have the highest TKW were G12 and the local landrace Saida 183. For the chlorophyll content and as shown in Table 2 the analysis of variance showed a significant effect of genotypes, the highest values registered by the introduced genotype G5 this one was in the same homogenize group of G2, G4, G8 and G18. Based on the origin of genotypes the analysis of variance demonstrated that the reflectance at Red, Green and the chlorophyll content there were significant difference between the two groups (local and introduce), for this raison the highest values of Chl were registered by the introduced genotypes (Table 2). As shown in Table 4 the ranking of the genotypes was based on the rank of each genotype for Senescence and Chl, GY and TKW parameters; the best genotypes were G5, G12, G11, G7, G3 and G2, respectively. The study of correlation showed a negative correlation between the mean of senescence, GY and TKW (r = - 0.63***, r = - 0.59 **, respectively); this correlation in good agreement with

Table 3: Genotypes ranking based on the Reflectance and Senescence indices.

Origin	Genotypes	Genotypes Ranks						
		Reflectance %				Senescence		
		Red	Green	Bleu	Score	S %	Sv	Score
Introduce	G1	26	26	26	21	2	2	2
	G2	18	17	19	15	6	25	12
	G3	9	9	15	7	20	7	9
	G4	20	22	24	19	21	20	17
	G5	5	3	7	3	17	24	17
	G6	11	12	23	13	22	22	18
	G7	15	13	13	10	19	18	15
	G8	17	10	17	11	9	21	11
	G9	10	8	11	6	12	9	7
	G10	19	20	22	17	10	11	7
	G11	4	4	4	2	3	12	4
	G12	14	14	12	9	1	1	1
	G13	22	18	20	16	24	14	16
	G14	23	25	16	18	15	23	16
	G15	3	2	1	1	13	4	5
	G16	13	11	5	6	25	8	13
	G17	6	6	8	4	26	3	10
	G18	7	7	14	5	8	13	7
	G19	1	5	9	3	14	6	6
	G20	12	19	10	10	16	15	12
	G21	21	21	18	16	5	19	8
	G22	2	1	3	1	18	17	14
Local	G23 (Fouarra)	25	24	25	20	4	16	6
	G24 (Saida 183)	24	23	2	14	7	5	3
	G25 (Tichedrette)	16	15	6	8	11	10	7
	G26 (Rihane 03)	8	16	21	12	23	26	19

Table 4: Genotypes ranking based on Agronomic traits.

Origin	Genotypes	Genotypes Ranks				
		Agronomic traits				
		Chlorophyll	GY	TKW	Score	Total Score
Introduce	G1	24	2	3	6	15
	G2	3	5	20	5	16
	G3	18	4	5	4	7
	G4	4	14	18	8	24
	G5	1	10	4	1	3
	G6	9	11	19	10	19
	G7	6	6	15	4	13
	G8	14	13	21	12	18
	G9	2	22	25	13	11
	G10	17	19	17	15	21
	G11	8	12	6	3	1
	G12	12	3	1	2	2
	G13	10	24	23	16	25
	G14	11	15	8	7	22
	G15	23	23	14	17	4
	G16	13	18	11	11	12
	G17	26	21	10	16	14
	G18	5	7	22	7	5
	G19	19	17	12	12	6
	G20	7	26	24	16	20
	G21	15	8	13	8	17
	G22	21	20	9	14	8
Local	G23 (Fouarra)	25	1	16	11	23
	G24 (Saida 183)	16	16	2	7	9
	G25 (Tichedrette)	22	9	7	9	10
	G26 (Rihane 03)	20	25	26	18	26

Rawson *et al*. (1983) and Ellen (1987). Contrary to these findings many studies have demonstrated that delayed senescence delays remobilization and leads to reduced grain weight (Yang *et al*. 1997).

CONCLUSION

The genetic diversity among genotypes explains the significant differences for all traits. Based on the origin effects the reflectance at Red, Green and Chlorophyll content are significantly difference between the local and introduce genotypes. The highest GY and TKW are registered in the local landrace Fouarra and Saida 183, respectively. The highest values of chlorophyll content registered by the introduce genotype G5; the values of the reflectance at Red, Green and Blue are varied from the local to the introduce genotypes. The ranking of genotypes based on all parameters suggested that the genotypes G11, G12, G5, G15 and G18, respectively (introduce genotypes) were the ideal genotypes under these conditions.

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