Chapter

Leaf Senescence in Wheat: A Drought Tolerance Measure

Hafsi Miloud and Guendouz Ali

Abstract

The present study was conducted on the experimental site of INRAA, unit research of Setif. A set of 10 genotypes of durum wheat (*Triticum durum* Desf.) planted during four cropping seasons (2009–2013). The objectives of this study are to evaluate the performance of some durum wheat genotypes and tested the efficiency of using senescence parameters in screening under semi-arid conditions. The analysis of variance demonstrates significant effects of genotypes and years on the grain yield and senescence parameters. Based on the means comparison, the values of total mean grain yield (2009–2013) varied from 37.84 q/ha for Oued Zenati to 44.7 q/ha for Altar84 with general mean of 42.71 q/ha. The mean rankings based on the mean grain yield demonstrate that the genotypes Mexicali75, Hoggar, and Sooty have the best ranking with highest grain yield. The mean values over years of Sa% varied between 47.91% for the genotype Oued Zenati and 59.45% for Waha. The genotypes with highest values for the parameter mid-senescence (Σ_{50s}) are the most tolerant and adapted genotypes.

Keywords: durum wheat, senescence, screening, semi-arid

1. Introduction

Durum wheat is one of the most cultivated cereals in the world; it is growing under the Mediterranean regions [1]. Water stress is the abiotic stresses limiting wheat distribution and productivity [2]. Water stress adaptation is considered as the major aim for breeding target in the stabilization of crop performance, by breeders and molecular biologists; at the moment, there is a lack of information to be able to measure with precision the plant resistance under drought stress conditions [3]. Photosynthesis is the primary source of dry biomass production and grain yield in plants. The improvements of leaf photosynthesis have occurred with the advance of breeding high-yielding cultivars. During the period of wheat spike growth, the important moment of assimilation that supplies carbon for the grain depends on the amount and quality of light on the surface of the green area after anthesis. This assimilation area normally decreases due to natural senescence and various stresses. Senescence is considered the final stage in leaf development; senescence in plants is defined as the age-dependent programmed degradation and degeneration process of cells, organs, or the entire organism, leading to death [4]. The most remarkable events in leaf senescence are the loss of chlorophyll and the disassembly of the photosynthetic apparatus, which result in decreases in the photosynthetic energy conversion capacity and efficiency. In addition, chloroplasts of senescing leaves show reduced volume, their shape is spherical, and the thylakoid system is reduced. In cereals, the processes involved in senescence are important because they occur during grain filling, and evidence suggests that early senescence may be yield-limiting [5]. Wheat genotypes vary in the timing of senescence initiation and also in the subsequent rate of leaf senescence. In wheat, the senescence rate was also found to be related to the yield under drought conditions [6, 7]. The quest of the causes of differences in leaf photosynthetic rate among interspecies and/or intraspecies of crops may be one of the important strategies of crop engineering [8]. In all these studies, leaf senescence was evaluated visually. Since senescence corresponds to yellowing due to chlorophyll loss [5], the identification of senescent parts of the leaf is quite easy. In this work, we used an alternative method for the evaluation of the leaf senescence based on numerical analysis of image. In addition, we study the efficiency of using the flag leaf senescence as tools for select adapted durum wheat genotypes under semi-arid conditions.

2. Materials and methods

2.1 Plant material and growth conditions

A set of 10 genotypes of durum wheat (*Triticum durum* Desf.) (**Table 1**) were planted during four cropping seasons (2009–2013), in the experimental fields of INRAA, Setif, Algeria (5°20′E, 36°8'N, 958 m above sea level) genotypes were grown in randomized block design with four replicates. Plots were 5 m $\times$ 6 rows with 0.20 m row spacing, and sowing density was adjusted to 300 g m^{-2}.

2.2 Agronomical and physiological measurements

Grain yield (GY) is determined from sub-samples taken from harvested grains of each plot. Leaf senescence (S) was evaluated by numerical image analysis (NIA) according to Hafsi et al. [9]. 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 analyzed using IPP (Image Pro Plus, Version 4, Media Cybernetics, Silver Spring, MA, USA) software. Senescence was expressed as the ratio of senesced area to total leaf area (in %). Measurements were carried out 10 times between flowering and the end of senescence on three flag leaves for each genotype. Ten dates of assessments were expressed in sums of temperatures after flowering ($\Sigma t_1 - \Sigma t_{10}$) and the corresponding senescence values ($S_1 - S_{10}$). In addition, the date of mid-senescence (Σ_{50}) was evaluated from the experimental curves S = f (Σ_t) as the sum of temperature corresponding to an S value of 50%. Data were analyzed using Costat; the analysis of variance was performed for senescence parameters and grain yield. Linear correlation analysis was used to determine the relationships between the traits measured.

Genotype	Origin	Genotype	Origin
Bousselem	ICARDA/CIMMYT	Altar84	CIMMYT
Hoggar	Spain	Dukem	CIMMYT
Oued Zenati	Algeria	Kucuk	CIMMYT
Polonicum	Algeria	Mexicali75	CIMMYT
Waha	ICARDA/CIMMYT	Sooty	CIMMYT

Table 1.
Name and origin of tested genotypes.

3. Results and discussion

The ANOVA analysis demonstrates significant effect of genotypes and years on senescence parameters and GY. Based on the means comparison, the values of mean grain yield (2009–2013) varied from 37.84 q/ha for Oued Zenati to 44.7 q/ha for

Genotype	Grain yield (q/ha)				Mean over
	2009/2010	2010/2011	2011/2012	2012/2013	all seasons
Oued Zenati	25.50(ab)	52.20(d)	21.45 (b)	47.11(ab)	37.84(b)
Altar84	29.31(a)	55.94(bcd)	24.86 (ab)	64.97(a)	44.79(a)
Sooty	26.56(ab)	63.14(abc)	27.33 (ab)	52.92(ab)	44.29(ab)
Polonicum	24.68(ab)	56.47(abcd)	32.68 (ab)	55(ab)	43.30(ab)
Waha	26.93(ab)	64.63(a)	35.24 (a)	37.31(b)	43.18(ab)
Dukem	22.00(b)	63.94(ab)	29.75 (ab)	44.44(ab)	41.87(ab)
Mexicali 75	31.93(a)	59.64(abcd)	32.90 (ab)	49.34(ab)	44.69(a)
Kucuk	26.50(ab)	53.96(d)	36.87 (a)	47.87(ab)	42.54(ab)
Hoggar	29.68(a)	60.05(abcd)	30.23 (ab)	47.03(ab)	43.42(ab)
Bousselem	29.81(a)	55.01(cd)	36.87 (a)	37(b)	41.26(ab)
Mean	28.00(c)	59.04(a)	30.81(c)	48.3(b)	42.72
Min	22.00	52.2	21.45	37.00	37.84
Max	31.93	64.63	36.87	64.97	44.79
Genotype effect	***	***	***	***	***
LSD 5%	6.45	8.15	13.60	22.26	6.45
Year effect	***				
LSD 5%	4.37				

N.B: Means followed by the same letter are not significantly different ($P \leq 0.05$).

Table 2.
ANOVA analysis and means comparison of grain yield over four cropping seasons.

Genotype	Ranking based on GY				Mean ranking	SD of ranking
	2009/2010	2010/2011	2011/2012	2012/2013		
Oued Zenati	8	10	9	6	8	1.48
$Altar_{84}$	4	7	8	1	4	2.74
Sooty	6	3	7	3	3	1.79
Polonicum	9	6	4	2	5	2.59
Waha	5	1	2	9	2	3.11
Dukem	10	2	6	8	7	2.96
Mexicali 75	1	5	3	4	1	1.48
Kucuk	7	9	1	5	6	2.96
Hoggar	3	4	5	7	3	1.48
Bousselem	2	8	1	10	5	3.83

Table 3.
Ranking of tested genotypes based on the grain yield.

$Altar_{84}$ with general mean of 42.71 q/ha. Based on the climatic data, the defavorable cropping season is the first one (2009–2010) with mean grain yield equal 27.29 q/ha; during this season, the grain yield varied between 22.0 q/ha for Dukem to 31.93 q/ha for $Mexicali_{75}$. In addition, the best season is 2010–2011 with mean grain yield of 58.49 q/ha, the highest grain yield registered by the genotype Waha (64.63 q/ha) (**Table 2**). The ranking based on the mean grain yield demonstrates that the genotypes $Mexicali_{75}$, Hoggar, and Sooty (**Table 3**) have the best ranking with low values of standard deviation in the changement of ranking over years (1.48, 1.48, and 1.79, respectively); the mean grain yield of these genotypes varied between 44.69, 44.29, and 43.42 q/ha, respectively. A highly significant genotype and years effects was noted for Sa% (average senescence) and the date of mid-senescence (Σ_{50s}) (**Table 4**); the mean values over years of Sa% varied between 47.91% for the genotype Oued Zenati and 59.45% for Waha. For the last parameter

Genotype	2009/2010		2010/2011		2011/2012		2012/2013		Mean over all seasons	
	S_a %	Σ_{50S}	Sa %	Σ_{50S}	Sa %	Σ_{50S}	Sa %	Σ_{50S}	Sa %	Σ_{50S}
Oued Zenati	49.30 (a)	290.9 (d)	44.51 (d)	356.78 (f)	48.56 (e)	350.01 (g)	49.26 (e)	240.95 (cd)	47.91 (e)	309.66 (g)
$Altar_{84}$	38.96 (e)	333.54 (a)	58.94 (ab)	593.49 (cb)	63.26 (ab)	596.72 (bc)	49.9 (e)	283.68 (ab)	52.77 (bc)	451.86 (b)
Sooty	42.57 (cd)	305.17 (c)	55.5 (bc)	594.93 (cb)	56.69 (cd)	598.16 (b)	56.82 (b)	196.90 (ef)	52.89 (bc)	423.79 (e)
Polonicum	43.24 (c)	312.82 (b)	51.53 (c)	479.54 (e)	55.85 (cd)	489.44 (e)	51.25 (d)	247.20 (c)	50.47 (d)	382.25 (f)
Waha	48.07 (a)	269.77 (e)	63.44 (a)	578.72 (c)	67.76 (a)	584.29 (c)	58.51 (a)	239.23 (cd)	59.45 (a)	418.00 (e)
Dukem	40.31 (e)	298.59 (c)	60.26 (ab)	515.37 (d)	57.64 (cd)	518.60 (d)	53.68 (c)	217.24 (de)	52.97 (bc)	387.45 (f)
Mexicali 75	35.31 (f)	338.85 (a)	54.18 (bc)	612.43 (ab)	55.63 (d)	615.66 (a)	47.35 (f)	289.63 (a)	48.12 (e)	464.14 (a)
Kucuk	45.19 (b)	286.63 (d)	54.12 (bc)	625.25 (a)	60.83 (bcd)	628.48 (a)	57.20 (ab)	190.54 (f)	54.33 (b)	432.73 (d)
Hoggar	40.95 (de)	316.92 (b)	57.53 (bc)	594.25 (cb)	60.12 (bcd)	597.48 (bc)	49.36 (e)	260.77 (bc)	51.99 (cd)	442.35 (c)
Bousselem	42.8 (cd)	334.46 (a)	56.79 (bc)	470.64 (e)	61.11 (bc)	445.87 (f)	47.84 (f)	281.84 (ab)	52.13 (cd)	383.20 (f)
Mean	42.67 (d)	308.76 (b)	55.68 (b)	542.14 (a)	58.74 (a)	542.47 (a)	52.12 (c)	244.80 (c)	52.3	409.54
Min	35.31	269.77	44.51	356.78	48.56	350.01	47.35	190.54	47.91	309.66
Max	49.3	338.85	63.44	625.25	67.76	628.48	58.51	289.63	59.45	464.14
Genotype effect	***		***		***		***		***	
LSD 5%	1.24	5.34	4.12	16.23	5.28	13.33	1.33	26	1.68	8.16
Years effect	***		***		***		***		***	
LSD 5%	1.01	5.20	1.01	5.20	1.01	5.20	1.01	5.20		

*** $P < 0.001$

Table 4.
ANOVA analysis and means comparison of senescence parameters over four cropping seasons.

Genotype	Ranking based on Senescence parameters								Mean ranking		Total mean ranking	SD of ranking	
	2009/2010		2010/2011		2011/2012		2012/2013		Sa%	Σ_{50S}		Sa%	Σ_{50S}
	Sa%	Σ_{50S}	Sa%	Σ_{50S}	Sa%	Σ_{50S}	Sa%	Σ_{50S}					
Oued Zenati	10	8	1	10	1	10	3	9	2	10	5	3.49	0.80
$Altar_{84}$	2	3	8	5	9	5	5	7	7	4	4	2.45	1.74
Sooty	5	6	5	3	4	3	8	10	5	5	3	1.47	2.58
Polonicum	7	5	2	8	3	8	6	8	3	9	5	1.94	1.36
Waha	9	10	9	6	10	6	10	3	10	8	8	0.49	2.23
Dukem	3	7	10	7	5	7	7	1	8	6	7	2.42	2.40
Mexicali75	1	1	4	2	2	2	1	6	1	1	1	1.10	1.85
Kucuk	8	9	3	1	7	1	9	4	9	2	4	2.23	2.93
Hoggar	4	4	7	4	6	4	4	5	4	3	2	1.26	0.63
Bousselem	6	2	6	9	8	9	2	2	6	7	6	1.96	3.29

Table 5.
Ranking of tested genotypes based on the senescence parameters.

(Sa%), the genotypes with lowest values are the preferable and adapted genotype. However, the genotypes with highest values for the parameter mid-senescence (Σ_{50s}) are the most tolerant and adapted genotypes; the mean values over years of mid-senescence varied between 464.14°C for the genotype $Mexicali_{75}$ and 309.66°C for the genotype Oued Zenati. The total mean rankings based on the senescence parameters demonstrate that the genotypes $Mexicali_{75}$, Hoggar, and Sooty are the best genotypes under these conditions (**Table 5**). Our study showed significant correlation between grain yield and the parameter mid-senescence (Σ_{50s}) ($r = 0.91^*$). Over 50 years ago, it was realized that the diversity in yield for most crops is mainly a consequence of variation in the duration, rather than the rate of photosynthetic activity [10], and so, delayed leaf senescence (i.e., stay-green) has long been considered to be a desirable trait in cereal breeding. Total flag leaf photosynthesis, chlorophyll content, the onset of senescence (at low nitrogen availability), and green leaf duration have all been found to be positively correlated with wheat grain yield [11].

4. Conclusion

The results of this study demonstrate that the genotypes with highest values for the parameter mid-senescence (Σ_{50s}) are the most tolerant and adapted genotypes. Based on the mean grain yield ranking, the genotypes $Mexicali_{75}$, Hoggar, and Sooty have the best grain yield. In addition, the screening based on the senescence parameters showed that the genotypes $Mexicali_{75}$, Hoggar, and Sooty are the preferable and adapted genotype. The combination between the rankings based on the GY and senescence parameters demonstrate that the genotypes $Mexicali_{75}$, Hoggar, and Sooty are the best and recommended genotypes under this condition.

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References

[1] Baldy C. Comportement des blés dans les climats méditerranéens. Ecologia Mediterranea. 1986;**XII**(3–4): 73-88

[2] Mastrangelo AM, Rscio A, Mazzucco L, Russo M, Cattivelli L, Di Fonzo N. Molecular aspects of abiotic stress resistance in durum wheat. Options Méditerranéennes, Series A. 2000;**40**:207-213

[3] Blum A. Crop response to drought and the interpretation of adaptation. Plant Growth Regulation. 1996;**20**: 135-148

[4] Lim PO, Kim HJ, Nam HG. Leaf senescence. Annual Review of Plant Biology. 2007;**58**:115-136

[5] Patterson TG, Moss DN. Senescence in field –grown wheat. Crop Science. 1979;**19**:635-640

[6] Mi GH, Tang L, Zhang FS. Nitrogen uptake and translocation during grain formation of two wheat cultivars with contrasting maturity appearance. Journal of South China Agricultural University. 1999;**3**:453-457

[7] Pajević S, Krstih B, Stankovih Z, Plešnicar M, Dencih S. Photosynthesis of flag leaf and second wheat leaves during senescence. Cereal Research Communications. 1999;**27**:155-162

[8] Jiang H, Wang XH, Deng QY, Yuan LP, Xu DQ. Comparison of some photosynthetic characters between two hybrid rice combinations differing in yield potential. Photosynthetica. 2002; **40**:133-137

[9] Hafsi M, Mechmeche W, Bouamama L, Djekoune A, Zaharieva M, Monneveux P. Flag leaf senescence, as evaluated by numerical image analysis, and its relationship with yield under drought in durum wheat. Journal of Agronomy and Crop Science. 2000;**185**:275-280

[10] Watson DJ. The physiological basis of variation. Advances in Agronomy. 1952;**4**:101-145

[11] Wang H, Mc Caig TN, De Pauw RM, Clarke JM. Flag leaf physiological traits in two high-yielding Canada Western red spring wheat cultivars. Canadian Journal of Plant Science. 2008;**88**:35-42