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Performance and Inheritance of the Stay Green Trait in Grain Sorghum (Sorghum bicolor L .) under Normal and Water Stress Conditions.

Iman .M.Hassan*, M.F.Saba*, M.A.El-Morshidy and M.Z.El-Hifny

Agronomy Dept.,Fac.Agric.,Assiut Univ.,Assiut ,Egypt.

*** Sorghum Res.Dept.,Field Crop Res.Institute,A.R.C,Egypt**

Abstract:

The objective of this research was to study the stay-green trait and its components in the Egyptian grain sorghum populations and investigate their inheritance. A random sample of six A-lines and six R-lines were used to produce thirty six hybrids by line × tester mating design. Six A-lines ,six R-lines , 36 hybrid and the check hybrid were evaluated both under normal irrigation and post flowering. Water stress via preventing the irrigation from booting stage until harvest at two locations, Sohag and Assiut cover reratis. Overrates Four characteristic traits of stay-green were estimated leaf area green, relative green leaf area duration, Absolute green leaf area and leaf area rettention . All the studied traits exhibited harmful depression resulting from post flowering water stress. The Assiut location described as unfavorable because of poor sandy soil of newly reclaimed land slightly saline soil . The GLA depression began early even before flowering and this depression amplified by water stress. The A-line, R-line and crosses displayed significant variances for all studied traits. The stay-green and its components mostly showed significant average heterosis toward better performance. Partitioning the genetic variance to additive and non-additive components pointed out that the non-additive gene effects were predominant and more common under unfavorable conditions. The estimates of narrow and broad sense-heritability suggested the success of selection for the stay green trait under the most favorable conditions

Key Words: Stay-green, green leaf area (GLA), relative green leaf area duration, absolute green leaf area duration, leaf area retention, heritability

Introduction:

Sorghum is an important cereal crop in semiarid regions of the world. One of the major challenges for sorghum improvement programs is to develop genotypes that have an advantage in water limited environments. Sorghum exhibits two distinct responses to drought stress (***Rosenow and Clark, 1981; Rosenow et al., 1983***). One response sesnonse occurs when plants are stressed during the panicle development stage prior to flowering, called pre-flowering, and the second occurs when plants are stressed

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after anthesis during grain development and is called post-flowering stress (***Walulu et al, 1994)***. Several genotypes with a high level of resistance at one stage may be susceptible at the other stage (***Rosenow et al., 1983)***. Stay green is an important trait associated with drought resistance at post flowering (***Walulu, et al, 1994***). And it is a particularly valuable trait in dual-purpose (grain plus fodder) sorghum (***van Oosterom et al, 1996)***. Stay green also increases sorghum resistance to stalk rot and charcoal rot (***Mughogho and Pande, 1984***). Stay-green or non-senescence is the delayed or reduced rate of normal plant senescence as it approaches maturity, resulting in greater functional leaf area during grain filling and extension of the photosynthetic capability of the upper canopy leaves ***(McBee, 1984)***. Genotypes possessing the stay green trait maintain more active photosynthetic leaves (***Rosenow et al., 1983; Mcbee, 1984***) and continue to fill their grains normally under drought occurring after flowering ***(Rosenow and Clark, 1981)*** than genotypes which lack this trait.Greater green leaf area duration during grain filling appears to be a product of different combinations of three distinct factors; green leaf area at flowering, time of onset of senescence and rate of leaf senescence. Further, all three factors appear to be independently inherices (***van Oosterrom et al, 1996***). These traits are useful for improving sorghum genotypes for drought tolerance since they have been found to improve the efficiency of selection for drought tolerance. Inheritance of the stay green has not been clearly described. ***Walulu et al (1994)*** suggested that the stay green trait is influenced by a major gene that exhibits various levels of dominant gene action depending on the environment in which evaluations are made.Two visual scaling methods are used to estimate stay-green trait. Estimation of Non-senescence or stay green by Visual stay green score (VSGS): was scored visually on a scale of 1 to 10 on an individual plant basis according to ***Walulu et al (1994).*** The 1 to 10 rating scale was based on the estimated portion of leaf death of normal size leaves; where 1= 0 to 10%, 2= 10 to 20%, etc., and 10= 90 to 100% leaf death. VSGS were estimated as average of five representative guarded plants tagged at flowering time for each plot to rate VSGS weekly. VSGS was estimated five times after flowering and the average of the five plants for each genotype was recorded. ***Wanous et al (1991)*** recorded that visual green leaf area rating correlated well ($r = 0.93$, $P<0.01$) with the percentage of green leaf area obtained by actual measurements of green leaf area. The second method, ***van Oosterom et al (1996)*** visually estimated the green leaf area percentage (GAP) of the upper six leaves of six representative plants per plot.The objectives of the present investigation were to study (i) the mode of gene action and heritability for the stay green, and (ii) the effect of environment on genetic parameters controlling this trait .

Materials and methods

Six sorghum restorer lines vis., randomly chosen Dorado-ICSP12, Dorado, Dorado-G113, Dorado-G114, ICSR92003 and ICSR93001 and six cytoplasmic male sterile lines (CMS-lines) i.e., ATX631, Apop32, Apop38, ICSA88005, ICSA88010 and SPGMA94021 were used to produce thirty six hybrids by the line × tester mating design ***(Kempthorne 1957)***. The primary seed propagation and manual crosses procedures were carried out Shandaweel Agricultural Research Station (SARS), Sohag in 2008 and 2009 growing seasons

In 2010 season, the resultant 48 gentypes (36crosses+6restorer +6CMS) and Shandaweell-6 hybrid (check) were evaluated in two field experiments in both(Arab El wamer), Assiut and(SARS) Sohag locations. The first experiment in each location was normally irrigated(normal irrigation) while the second experiment was normally irrigated until the booting stage then irrigation was stopped until harvest which leads to water stress during post flowering and seed filling(water stress).The soil was extremely different in both locations (Table 1), The soil at SARS was loamy clay soil, while the soil of the Assiut location was sandy calcareous(newly reclaimed sandy soil).

Table 1: Physical and chemical characteristic of representative soil samples from field experiment sites.

Soil properties	Assiut	Sohag
Particle distribution		
Sand (%)	96.72	49.3
Silt (%)	2.12	16.3
Clay (%)	1.16	34.4
Soil texture	Sandy	Clay
Field capacity (%)	9.92	39.60
Water saturation	20.58	68.40
EC mmhose/cm (1:1)	0.35	0.84
pH (1:1 water suspension)	8.65	7.6
Organic mater %	0.24	1.3
Soluble cations (meq/1)		
Ca	1.73	3.6
Mg	1.00	2.9
Na	0.56	2.2
K	0.17	0.36
Soluble anions (meq/1)		
$CO_3 + HCO_3$	1.70	9.5
Cl	1.34	2
Total nitrogen (%)	0.003	96.1
Available Phosphorus (ppm)	8.30	12.1
Avalable micro-nutrients, ppm		
F	1.85	7.7
Mn	1.59	3.9
Zn	0.33	0.27
Cu	0.38	0.27
Soil type	Sandy caleareous	clay loam

Each experiment was conducted in a randomized complete block design with three replications. The experimental plot was one row of four meters long and 60 cm wide. Planting was done in hills spaced 20 cm apart and hills were thinned to two plants/hill. The common agricultural practices of growing grain sorghum were properly applied as recommended in the district.

Studied traits

The stay-green trait was estimated according to ***van Oosterom et al (1996)*** for the upper ten leaves of five representative plants per plot. So, a logistic function to describe the patterns of leaf senescence, was as follows,

$Y = UL/(1+Ae^{Bt})$, where

Y= is the green area percentage (GAP).

T= the number of days after flowering.

A = is constant.

E= is an irrational and transcendental constant approximately equal to 2.718 (the base of natural logarithm)

B= is the senescence rate.

The weekly collected data of GAP for each genotype and each plot were fitted to the above equation. From the fitted function and the measured GAP the related variables were derived for each plot. In the current paper the following traits related to stay green are=1- **Green leaf area/plant at flowering (GLA)** (cm^2): the maximum length by maximum width of the fifth leaf below the flag leaf times sue number of green leaves by 0.75, according to ***Kirby and Atkins (1968)***.

2- Relative green leaf area duration (GLAD%) after flowering was defined for each plot as the area under the logistic curve (the upper equation), estimated by linear interpolation for 0.2/day intervals from flowering until 28 days after flowering (two days before harvesting) as a percentage of maximum green leaf area (100%) see figure 1.

3- Absolute green leaf area duration (GLAD m^2); the total active leaf area during seed filling from flowering until harvesting.

4- Leaf area retention (LAR cm^2); the leaf area 28 days after flowering or total green area at the last measurement before harvest.

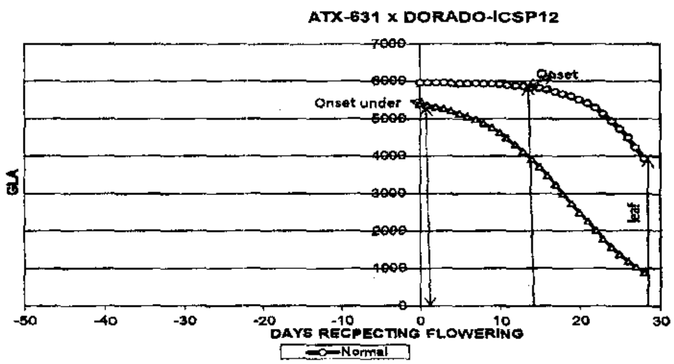

Figure 1: Green leaf area percentage GAP of the hybrid ATX631 x Dorado-ICSP112 under normal and stressed irrigation at Shandawell Agricultural Research Station (SARS).

According to ***Hallauer and Miranda (1982),*** the analysis of variance of North Caroline design II the total variation due to males (m), females (f) and the interaction of males with females. The expectation of mean squares (Table 2) expressed in terms of covariances between full-sibs and half-sibs families is presented in Table2. So $\sigma^2_m = \sigma^2_f$ = COV HS= ½ σ^2A and σ^2_{fm} = COV FS - COV HS$_m$ - COV HS$_f$= (¼σ^2 D), where f=1 (f is the inbreeding coefficient) for inbred lines. The additive variances for males and females were calculated according to ***Singh and Shaudary (1985)*** as follows:

Phenotypic variance (σ^2_p)

$= \sigma^2_e + \sigma^2_A + \sigma^2_D$

Genotypic variance (σ^2_G)

$= \sigma^2_A + \sigma^2_D$

Broad sense heritability (h^2_b)

$= \sigma^2_G / \sigma^2_p$

Narrow sense heritability (h^2)

$= \sigma^2_A / \sigma^2_p$

Average degree of dominance

$= (2\sigma^2 D / \sigma^2 A)^{½}$

Table2: Analysis of variance for 48 genotypes evaluated under each irrigation treatment at each location.

Source of variance	d.f	EMS
Replicate (Rep)	r-1 = 2	
Genotypes (G)	G-1 = 47	
Parents (P)	P-1 = 11	
Crosses	C-1 = 35	
Males	m-1 = 5	$\sigma^2_e + r\sigma^2_{fm} + rmf\sigma^2_f$
Females	f-1 = 5	$\sigma^2_e + r\sigma^2_{fm} + rm\sigma^2_m$
Males x females	(m-1)(f-1) = 25	$\sigma^2_e + r\sigma^2_{fm}$
Error	(r-1) (g-1) = 94	σ^2_e

r= no. of replications σ^2_e =Variance due to error.

σ^2_m = Variance due to male lines (tester) σ^2_f = Variance due to female lines

Results and discussion

1-Performance:

Analysis of variance for GLA, relative green leaf area(GLAD%), absolute green leaf area (GLAD) and LAR under normal and water stress conditions in each location revealed highly significant differences among all genotypes, i.e. Parents, F_1 crosses and the check hybrid. Combined analysis of variance, Table 3, over the two irrigation treatments showed highly significant mean squares for irrigation, genotypes and Irr. × Gen. interaction for all studied traits

Table 3: Combined analysis of variance over two water regimes at two locations of stay green traits for parents , their crosses grain sorghum (line x tester) and a check hybrid.

S . O. V	d.f.	Mean Squres							
		GLA		GLAD%		GLAD M2		LAR	
		Sohag	Assiut	Sohag	Assiut	Sohag	Assiut	Sohag	Assiut
Irrigation (Irr)	1	47012082**	25896707**	31852702**	15161435**	642**	338**	166396612**	41130000**
Error a	4	34027	173297	1.82275	126292	7.90	3.20	165571	10358050
Genotypes (G)	48	3752216**	1028583**	291207**	335138**	25.34**	7.80**	3097210**	513750**
G vs .Check .	1	21630	190359	2114483**	97887	49**	2.67*	5428668**	80000**
Among Genot.	47	3831591**	1046417**	252414**	340186**	24.83**	7.90**	3047604**	522979**
Parents (P)	11	4325008**	789236**	544104**	510517**	32.58**	8.46**	3123382**	852189**
Crosses (C)	35	2376598**	1080313**	167660**	229867**	18.53**	7.92**	2403212**	416686**
P vs. C	1	49328749**	2689032**	10196	2327682**	160.37**	1.29	24767776**	621925**
Females (F)	5	4884964**	1881020**	429951**	372481**	39.89**	14.25**	4956018*	827600**
Males (M)	5	1848977**	242652/**	237969**	560095**	26.22**	20.69**	3740784*	867800**
F × M	25	1980449**	650929**	101140**	135299**	12.71**	4.10**	1625137**	244280**
Irr. × G	47	432251**	685510**	218620**	68131**	9.1**	3.30**	1691084	218723**
Error b	192	64793	75708	27623	21870	1.04	0.44	217015	42714

*, ** are significant at P<0.05 and p< 0.001 respectively

Table (4):Mean square for the stay green trait under normal and water stress conditions in Sohag and Assuit locations.

Source of Variance	d.f	Mean Squares							
		GLA				GLAD%			
		Sohag		Assuit		Sohag		Assuit	
		Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Replication	2	30226.75	34858.32	331942.46*	3131.35	68223.22	55678.18	229197.7**	56024.72
Genotypes(G)	47	2153686.94**	2110155.22**	783260.50**	948665.95**	237945.86**	230590.43**	174390.56**	233926.26**
Parents	11	2637527.81**	2151292.22**	212348.96**	1010277.71**	170197.79**	510293.57**	125372.01**	510001.08**
P vs. C.	1	22372302.30**	27068205.66**	1064137.14**	1657642.84**	1056152.67**	1348288.84**	940121.31**	1411417.03**
Crosses	35	1423947.94**	1384139.30**	954664.79**	909045.78**	235860.77**	110749.49**	167918.37**	113517.30**
Females (F)	5	1282495.58**	782836.01**	2063401.77**	2552045.07**	407192.89**	212637.59**	467118.90**	202411.62**
Males (M)	5	3206755.92**	2369088.09**	1555507.75**	791980.91**	431993.48**	116803.13**	280611.64**	121170.83**
F X M	25	1095676.82**	1307410.20**	612748.80**	603858.89**	162367.80**	89161.14**	85539.60**	94207.73**
Error	94	58459.17	73107.75	70412.44	83954	34343.75	22466.1593	20621.57	22480.31
		GLAD				leaf retention			
Replication	2	2.39	0.94	6.3539**	0.4209	240901.90	22974004.58	311050.15**	2493.56
Genotypes(G)	47	25.14**	8.69**	6.3438**	4.86**	3989900.10**	22686626.65*	454843.25**	284993.31**
Parents	11	23.39**	14.70**	2.91**	8.01**	2873289.06**	986433.03*	495713.12**	502575.38**
P vs. C	1	233.66**	7.26**	0.19	1.36	47696849.30**	8042127.09	390742.81*	313039.66**
Crosses	35	19.74**	6.84**	7.5985**	3.97**	3092065.02**	29925101.78*	443829.88**	215809.05**
Females (F)	5	34.91**	9.90**	20.23**	10.14**	5528269.46**	32759581.19*	1031238.27**	327193.04**
Males (M)	5	37.14**	12.04**	13.75**	3.42**	6535874.55**	30833259.56*	814181.11**	295081.62**
F X M	25	13.22**	5.19**	3.84**	2.85**	1916062.23**	29176574.34	252277.95**	177677.74**
Error	94	1.42	0.7199	0.5093	0.3706	364735.11	22984002.65	60406.91	24590.8286

Similar results have been represented by (***van Oosterom et al., 1996;Borrell et al., a&b2000); Munamava and Riddoch., 2001; Viswanathan and Francis., 2002; Okiyo et al., 2004 and Maseresha, 2010***).

Studied traits:

1-Green leaf area at flowering (GLA, cm²):-

The average green leaf area (GLA) at flowering for evaluated genotypes under the two water regimes at Sohag and Assiut locations are presented in Table 5. The general mean of GLA of the studied genotypes in Sohag and Assiut locations under normal and water stress conditions were 5765, 4965, 2850 and 2257cm^2, respectively. These results revealed the great difference between locations in their influence on green leaf area with the superiority of Sohag location where GLA was double its value at the Assiut location. This difference may be due to soil characteristics such as field capacity, salinity level and soil alkalinity that impose abiotic stresses on plant growth. Water stress led to about 14% and 21%descant in GLA at Sohag and Assiut locations, respectively. The soil nature supported water preventing to amplifying the GLA depression to be about 39% of normal conditions in Sohag location. However, this depression was observed on green leaves number as well as the leaf area of the fifth leaf (non- published data). These results were compatible with similar results obtained by ***El-Bakry et al (2002)*** who reported that GLA was depressed

under drought stress at 100 days from emergence to be about 87% of normal irrigation (393.1 cm^2). ***Okiyo et al (2004)*** reported that leaf length was reduced from 38.9 to 35.3 cm under water stress.The line sample showed significantly great variances of GLA, which ranged from 3360 to 6640 cm^2 which encourage the investigators to complete their objectives. The composite crosses of those lines displayed GLA ranging from 4416 to 7337 cm^2. These three measurements displayed the average heterosis effects toward increasing GLA; the analysis of variance for this trait ensured this deduction. These results are in harmony with those obtained by ***Rao et al (1999)*** who found that hybrids produced more leaf area than their parents. ***van Oosterom et al (1996)*** reported that F_1 crosses produced higher leaf area at flowering than their parents. Moreover ***Okiy et al (2004)*** reported that leaf width of F_1 crosses was 82.02% higher than their parents.However, the analysis of variance suggested that genotypes responded differently to water stress, since the mean squares of the interactions of lines, hybrids and lines vs. hybrids were highly significant. The best stay-green genotypes conserve most GLA until harvest and the early senescent genotypes age faster, enabling us to identify stay-green and senescent genotypes. Several investigators discussed GLA behavior ***(Mughogho and Pande,1984;Tenkouano et al, 1993; Walulu et al, 1994 and van Oosterom et al 1996)***.The best stay-green A-line was APOP-32, converted 93.15% of its GLA under water stress at Sohag location; other gantries had had GLA were 46.0 and 23.12% under normal and water stress conditions in Assiut location. It was apparent that the harsh condition on the latter location was more detrimental to this line. On the contrary, ICSR 88010 was the worst A-line that conserved about 72.78, 62.67 and 58.19 under water stress in Sohag and under normal and water stress in Assiut, respectively. This A-line also was adapted to Assiut conditions. Regarding the restorer lines, the line Dorado-G114 conserved 98.44, 63.47 and 56.60% under water stress in Sohag , normal and water stress in Assiut, respectively, while the R-line ICSR 93001 displayed poor response to the latter conditions conserving 67.8, 51.98 and 26.63% with the same above arrangement.The best stay-green hybrid was (ICSA99005 x ICSR93001), which kept 97.47, 49.99 and 29.12% active green leaf area under water stress in Sohag and under water normal and water stress conditions in Assiut, respectively. Oppositely , the worst senescent hybrid was (APOP32 x Dorado-G113) which conserved 66.56, 45.58 and 24.46% GLA under water stress in Sohag, and normal and water stress conditions in Assiut, respectively. The different percentages decrement under Sohag and Assiut suggested different mechanisms rolling leaves senescence under causing factors. In Sohag 19 and 21 F_1 crosses significantly surpassed the check hybrid in GLA under normal and water stress conditions, respectively. In Assiut 3 and 16 F_1 crosses significantly surpassed the check hybrid in GLA under normal and water stress conditions, respectively

2- Relative green leaf area duration (GLAD%)

The estimated relative green leaf area duration (GLAD%) for each evaluated genotype under the two treatments in Sohag and Assiut locations are presented in Table 5.Obriously , this estimate was of the area bordered by the logistic curve, the two axes and leaf area retention (see Figure 1); and it was calculated by linear interpolation for 0.2/days intervals from flowering until 28 days after flowering therefore, dividing this estimate by 28 the result is the average relative GLA and is a good estimate of stay-green regardless the actual GLA. This estimation of stay-green has two leaf area components, viz., the onset and senescence rate which are not presented in the current paper.The general mean of GLAD% of the studied genotypes under normal and water stress in Sohag and Assiut location were 2135, 1476 and 1913, 1217.81, respectively. These results indicate that the onset of senescence and/or its rate led to more decrease of GLAD% in Assiut than Sohag location, while the decrement due to water stress in Sohag was severe.The average GLAD% of the randomly used lines were 1982, 1626, 2050 and 1455 under normal and water stress condition in Sohag and Assiut, respectively. On the other side, the average GLAD% of the derived crosses of these lines were 2179, 1401, 1863 and 1114 under normal and water stress in Sohag and Assiut, respectively. These senates apneas contradictory. There were highly significant average heterosis toward higher GLAD% under normal irrigation in the more productive location (Sohag) accompanied with non-significant interaction of the average heterosis with irrigation treatment. However, the contrary was observed in Assiut location where non-significant average heterosis under normal irrigation and highly significant interaction with irrigation treatment were found. Nevertheless, the previous suggestion that different mechanisms of rolling leaf senescence under Sohag and Assiut conditions would illustrate these confused results. But ***van Oosterom et al (1996)*** found that crosses produced relative GLAD greater than their parents.The best A-lines showing the highest GLAD% were APOP-38 (1968) and SPGMA 94021 (2129), while the worst lines were ICSA-88010 (1733) and ATX-631 (1744) in Sohag and Assiut, respectively. Regarding the restorer lines, the best lines were Dorado (2287) and Dorado-ICSP12 (2483) in Sohag, Dorado-G114 (2412)in Assiut, while the worst R-lines were ICSR92003 (1652) and the same R-line (1809) in Sohag and Assiut respectively. The best hybrid was (APOP-38 x Dorado-G114) which showed GLAD% of about 2586, 1697, 2095 and 1364 under normal and water stress in Sohag and Assiut, respectively. On the other hand, the hybrid (ICSA 88005x Dorado-ICSP12) showed an estimated GLAD% of about 1573, 1645, 1792 and 1312 under normal and water stress in Sohag and Assiut conditions, respectively. which was the worst estimate under normal irrigation in Assiut. Two F_1 crosses significantly surpassed the check hybrid in GLAD% under normal condition in Assuit . All F_1 crosses were not significantly different from compared with the check hybrid for GLAD% under both treatments under Sohag conditions.

3-Absolute green leaf area duration

The estimation of absolute green leaf area duration (GLAD m^2) for all evaluated genotypes under the two water regimes in Sohag and Assiut locations are presented in Table 6. According to ***van Oosterom et al (1996)***, absolute GLAD result values from multiplying the relative GLAD% by the actual GLA at flowering, so it is a good indication of the effective stay-green trait that influences grain yield via active photosynthetsis during the seed filling period. The general means of GLAD of the studied genotypes in Sohag and Assiut locations under normal and water stress conditions were 12.42, 7.31, 5.52 and 3.38m^2, respectively. These results reveal the great difference in GLAD estimates among locations with great active leaf area after flowering so that it was double of GLAD in Sohag location under normal irrigation. This depression could be due to variation in soil characteristics such as field capacity, soil salinity intensity and soil alkality that impose abiotic stresses on growing plants. Water stress decreased GLAD by about 41.17% and 38.70% in Sohag and Assiut locations, respectively.Soil characteristics enhancing water conservation amplified the GLAD depression to about 27.23% of normal conditions in Sohag location. These results are in harmony with those obtained by ***Borrell et al (2000 b)*** who found that water stress at post flowering reduced green leaf area at maturity by 67% compared with full irrigation. ***Munamava and Riddock (2001)*** stated that the effective green leaf area at grain filling decreased with water stress at the vegetative, booting and flowering stages. Generally, the random sample of lines used showed that GLAD estimates were about 10.19, 6.83, 5.55 and 3.55 m^2 in Sohag and Assiut locations under normal and water stress conditions, respectively. The crosses involving of these lines gave estimates of about 13.13, 7.34, 5.47 and 3.32 m^2. These estimates resulted in average heterosis expressed in Sohag only, while in Assiut there was no average heterosis.

Table5: Green leaf area and the relative green leaf area duration of 6 A-lines, 6 R-lines, their line × tester crosses and check hybrid tested under two water regimes at two locations

Genotypes	GLA cm^2				GLAD%			
	Sohag		Assiut		Sohag		Assiut	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
APOP-32xDorado-G114	6880	6629	2793	2391	1936	1352	1788	1031
APOP-38xDorado-G114	5957	5567	2727	2601	2586	1697	2095	1253
ATX-631xDorado-G114	5703	4974	2496	2597	2067	1511	1900	1178
ICSA 88005xDorado-G114	6600	4974	2553	2609	2206	1199	1657	1000
ICSA 88010xDorado-G114	5333	4495	3211	2776	2027	1444	1858	1070
SPGMA 94021xDorado-G114	5693	5209	3270	2328	2187	1344	1830	1092
APOP-32xDorado	6878	5750	3859	2898	2485	1493	1988	1378
APOP-38xDorado	6066	5771	4181	3537	2451	1741	2193	1160
ATX-631xDorado	6146	4363	3376	2973	2248	1586	2013	1019
ICSA 88005xDorado	5482	5059	2365	1380	2369	1123	1684	1033
ICSA 88010xDorado	6604	5961	2673	3635	2264	1682	2391	1016
SPGMA 94021xDorado	6553	5336	3403	2679	1941	1531	2238	1164
APOP-32xDorado-G113	6244	4156	2846	1527	2208	1133	1895	1137
APOP-38xDorado-G113	6376	5944	4182	1184	2526	1126	2158	1408
ATX-631xDorado-G113	5407	4304	2226	1567	2467	1073	1515	1364
ICSA 88005xDorado-G113	7051	6509	2246	1452	2352	1288	1707	1026
ICSA 88010xDorado-G113	6766	5646	3554	2706	2465	1724	2286	1305
SPGMA 94021xDorado-G113	4416	3634	3335	2177	1916	1132	1425	1085
APOP-32xDorado-ICSP12	6698	5104	3371	2699	2206	1711	2157	1060
APOP-38xDorado-ICSP12	6170	5765	3034	1854	2574	1470	1992	1349
ATX-631xDorado-ICSP12	6315	5808	3256	1858	2250	1364	1970	1111
ICSA 88005xDorado-ICSP12	6603	5689	2292	2371	1573	1645	1792	1390
ICSA 88010xDorado-ICSP12	5762	5384	3320	1923	2154	1393	2034	1148
SPGMA 94021xDorado-ICSP12	5262	4644	2995	2082	2232	1318	2107	1044
APOP-32xICSR92003	5601	5271	2002	2384	2336	1116	1632	1312
APOP-38xICSR92003	5648	5398	2303	2310	2188	1638	1842	1021
ATX-631xICSR92003	4450	4216	2255	2496	1625	1403	1830	1099
ICSA 88005xICSR92003	6295	4441	2067	2543	1795	1509	1712	1188
ICSA 88010xICSR92003	5599	5283	2322	2727	1873	1481	1765	1177
SPGMA 94021xICSR92003	5398	4710	2972	2202	1592	1361	1719	1116
APOP-32xICSR93001	7337	5540	2429	2232	2461	1264	1550	1168
APOP-38xICSR93001	5400	4890	2667	2030	2324	1418	1777	1198
ATX-631xICSR93001	5021	4512	2852	2574	1974	1314	1557	1011
ICSA 88005xICSR93001	5573	5432	2786	1623	1844	1266	1685	1032
ICSA 88010xICSR93001	6443	6050	3268	2131	2222	1244	1778	1028
SPGMA 94021xICSR93001	6012	5417	2589	2481	2534	1333	1552	1033
mean of cross	5993	5218	2891	2320	2179	1401	1863	1144
Male parents								
Dorado-G114	4838	3961	2826	2449	2189	2174	2412	1974
Dorado	5127	5047	3254	2902	2287	2114	2297	1914
Dorado-G113	6366	5677	2591	2386	2022	1457	1867	1257
Dorado-ICSP12	6640	4885	2663	2666	2483	2125	2223	1925
ICSR92003	4691	3477	2664	2299	1652	1642	1809	1442
ICSR93001	5904	4003	3068	1572	1923	1236	2079	1046
mean of male lines	5594	4508	2844	2379	2092	1791	2114	1591
Female parents								
APOP-32	5622	5237	2586	1300	1883	1144	1849	1005
APOP-38	5226	4355	2801	1899	1968	1473	2119	1044
ATX-631	4556	3992	2451	925	1765	1095	1744	1285
ICSA88005	4444	3865	2295	1896	1952	1672	2033	1087
ICSA88010	4217	3069	2643	2454	1733	1269	2035	1497
SPGMA 94021	3360	3029	2467	2125	1925	2112	2129	2000
mean of female lines	4570.833	3924.5	2540.5	1766.5	1871	1461	1985	1319
General mean	5765	4965	2850	2257	2135	1476	1913	1224
check(Shandaweel 6)	5752	4859	3284	2175	2416	2370	2095	1300
R. L. S. D 0.05	246	273	277	303	202	154	160	158

These results are in harmony with those of ***van Ooserom et al*** 1996 who reported that F_1 exceeded the best parent for absolute GLAD. However, the analysis of variance suggested that genotypes responded differently to water stress, since the mean squares of the interactions of lines, hybrids and lines vs. hybrids were highly significant.

The best stay-green genotypes retain most GLAD until harvest while the worst senescent genotypes reach aging too fast, consent making its possible to identify stay-green and senescent genotypes.

The best A-line that displayed the highest GLAD at Sohag was APOP-32 (10.63 m^2) but this GLAD value declined to 5.98 m^2 due to water stress, outspending estimates at Assiut were 4.78 and 1.50 m^2 under normal and water stress conditions, respectively. This line was stay-green under favorable conditions and harsh conditions weaken and fasten senescence process. On the contrary, the SPGMA 94021 A-line showed the lowest GLAD under the favorable conditions and slightly conserved its active green area estimates were 6.48, 6.40, 5.18 and 4.51 m^2, so it had the worst GLA but it had the weakest senescence mechanism. Regarding the restorer lines, the highest estimates of GLAD at Sohag were obtained by Dorado-ICSP12 (16.48 and 10.43 m^2)under normal and water stress; however, this line moderately conserved its GLAD at Assiut (5.94 and 5.64 m^2). Fortunately, the large GLA can exist with weakened senescence mechanism.***van Oosterom et al*** **(1996)** stated that the stability of genotypic expression of stay green expressed as GLAD would depend on the stability of the contribution of stay-green components that delayed senescence and/or reduced senescence rate. The highest GLAD estimate under normal irrigation at Sohag of 18.05 $m^2$was obtained for the cross (APOP-32 x ICSR93001). The lowest GLAD estimates under normal irrigation at Sohag were obtained for the cross (ATX-631 x ICSR92003) which displayed estimates of 7.23, 5.9, 4.11 and 3.51 m^2 under normal and water stress in Sohag and Assiut location, respectively.These results are in harmony with those of ***van Oosterom et al (1996)*** who reported that the F_1 exceeded the best parent for absolute GLAD. Ten F_1 crosses showed significantly higher GLAD than check hybrid under normal irrigation at Sohag. Five and 10 F_1 crosses significantly surpassed the check hybrid in GLAD under normal and water stress, respectively, in Assuit .

4-Leaf area retention (LAR)

The dual-purpose sorghum cultivars essentially depend on the stay-green trait. The fodder yield and leaf stem ratio require high green leaves weight at harvest, which is realized through great leaf area retention. In the current investigation, the average LAR estimates were 3165, 1661, 1509 and 761 cm^2under normal and water stress at Sohag and Assiut, respectively(Table 6). LAR was a very sensitive trait under harsh conditions, and is more important to detect the stay-green genotypes. Therefore, genotypes maintaining a high LAR are considered stay-green, while the ratio of the lost portion of the active green leaf (depression ratio) expresses the sensitivity of the system rolling stay green trait under different abiotic stresses. These results agree with ***&van Oosterom et al(1996)***.

Regarding the A-lines, the highest LAR estimate was obtained for ICSA88005 (2045 cm^2), while the LAR depression ratios were 45.6, 40.6 and 72.2% under water stress at Sohag, normal and water stress conditions at Assiut, respectively, indicating that system rolling stay green was sensitive. The lowest LAR estimate was obtained for ATX-631 (872 cm^2) with depression ratios which were -4.36, -39.1 and 75.7% under water stress at Sohag and normal and water stress at Assiut, respectively.

R-lines with the highest LAR was Dorado-ICSP12 (4472 cm^2) with depression ratios of 50.7, 60.2 and 72.9% under water stress at Sohag, normal and water stress conditions in Assiut, respectively, while the lowest line was ICSR92003 (1377 cm^2) with 34.4, 5.1 and 74.2% depression ratios under water stress in Sohag, normal and water stress in Assiut, respectively. The best hybrid in LAR was (ICSA-88010 x Dorado-G113) which displayed 5663 cm^2 with depression ratios of 46, 61.4 and 74.1% under water stress at Sohag and normal and water stress conditions in Assiut, respectively. On the other side, the worst LAR shown by (ATX-631 x ICSR92003) 1867 with depression ratios of 27.8, 43.7 and 57% under water stress at Sohag and normal and water stress condition in Assiut, respectively. Ten F_1 crosses significantly exceeded the check hybrid under normal irrigation at Sohag. Six and two F_1 crosses significantly surpassed the check hybrid in LAR under normal and water stress respectively at Assiut. Finally the LAR of sampled lines ranged from 872 to 4472 cm^2 with an average of 2154 cm^2, compared with the range of their derived crosses (from 1867 to 5663 with average 3485), indicating the existence of significant average heterosis toward increased LAR.(Table 6).

Table 6: Absolute green leaf area duration (GLAD) and green leaf area retention of 6 A-lines, 6 R-lines and line × tester their crosses under two water regimes and two locations.

Genotypes	GLAD m^2				Leaf area retention cm^2			
	Sohag		Assiut		Sohag		Assiut	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
APOP-32xDorado-G114	13.32	8.96	5.01	3.23	2974	1836	1315	658
APOP-38xDorado-G114	15.42	9.51	5.73	4.44	4919	1563	1452	733
ATX-631xDorado-G114	11.77	7.52	4.74	3.97	2155	1453	1199	771
ICSA 88005xDorado-G114	14.55	5.97	4.25	3.14	2659	837	1086	437
ICSA 88010xDorado-G114	10.82	6.49	5.97	4.01	2167	1154	1697	719
SPGMA 94021xDorado-G114	12.46	7.00	5.98	3.13	2780	1309	1496	580
APOP-32xDorado	17.10	8.58	7.69	4.30	4735	1754	2053	884
APOP-38xDorado	14.89	10.06	9.20	6.21	3926	1650	2018	1001
ATX-631xDorado	13.82	6.94	6.80	4.73	2684	1496	1490	1026
ICSA 88005xDorado	13.00	5.68	4.04	1.56	3818	1326	1234	365
ICSA 88010xDorado	14.95	9.99	6.41	6.09	3448	2399	1735	1465
SPGMA 94021xDorado	12.75	8.15	7.65	4.11	3497	1598	2156	810
APOP-32xDorado-G113	13.80	4.71	5.41	1.73	3686	1044	1674	385
APOP-38xDorado-G113	16.11	6.69	9.03	1.33	5111	1473	2329	292
ATX-631xDorado-G113	13.37	4.62	3.38	1.67	4502	1020	877	365
ICSA 88005xDorado-G113	16.58	8.39	3.85	1.87	4904	1987	1124	444
ICSA 88010xDorado-G113	16.69	9.73	8.13	4.67	5663	3058	2183	1465
SPGMA 94021xDorado-G113	8.48	4.10	4.75	2.47	2494	831	1419	502
APOP-32xDorado-ICSP12	14.77	8.74	7.29	4.62	4426	1632	2063	864
APOP-38xDorado-ICSP12	15.88	8.48	6.08	2.72	5079	2483	1724	789
ATX-631xDorado-ICSP12	14.22	7.92	6.41	2.54	2773	2099	1708	672
ICSA 88005xDorado-ICSP12	10.38	9.31	4.11	3.86	2476	2554	1271	1058
ICSA 88010xDorado-ICSP12	12.39	7.50	6.77	2.68	3629	1942	1651	696
SPGMA 94021xDorado-ICSP12	11.73	6.13	6.32	2.75	3186	1418	1616	636
APOP-32xICSR92003	13.08	5.89	3.26	2.68	3865	1230	965	558
APOP-38xICSR92003	12.38	8.88	4.25	3.73	3471	2206	1217	924
ATX-631xICSR92003	7.23	5.90	4.11	3.51	1867	1348	1050	803
ICSA 88005xICSR92003	11.30	6.70	3.54	3.85	3013	1642	1042	944
ICSA 88010xICSR92003	10.46	7.83	4.10	4.04	3014	1845	1200	954
SPGMA 94021xICSR92003	8.59	6.42	5.11	3.00	2084	1570	1611	734
APOP-32xICSR93001	18.05	6.98	3.75	2.79	4824	1405	947	565
APOP-38xICSR93001	12.55	6.93	4.72	2.93	3144	1628	1391	686
ATX-631xICSR93001	9.89	5.91	4.45	3.40	2289	1176	1267	674
ICSA 88005xICSR93001	10.29	6.88	4.66	2.05	2677	1596	1395	474
ICSA 88010xICSR93001	14.32	7.51	5.83	2.64	3191	1691	1586	593
SPGMA 94021xICSR93001	15.23	7.21	4.03	3.30	4346	1775	1025	811
Mean of crosses	13.13	7.34	5.47	3.33	3485	1640	1480	732
	Male parents							
Dorado-G114	10.64	8.62	6.82	5.34	2686	2364	2175	1457
Dorado	11.74	10.66	7.50	6.14	2851	2601	2459	1475
Dorado-G113	12.88	8.27	4.84	3.47	3103	2028	1458	855
Dorado-ICSP12	16.48	10.43	5.94	5.64	4472	2205	1781	1213
ICSR92003	7.73	5.70	4.81	3.87	1377	1451	1406	945
ICSR93001	11.34	4.93	6.44	1.94	1816	1192	1724	468
Mean of male lines	11.80	8.10	6.06	4.40	2718	1974	1834	1069
	Female parents							
APOP-32	10.63	5.98	4.78	1.50	1546	1457	1360	368
APOP-38	10.22	6.42	5.94	2.80	1714	1707	1810	742
ATX-631	8.05	4.36	4.29	1.01	872	910	1213	212
ICSA88005	8.74	6.38	4.67	3.20	2045	1113	1215	569
ICSA88010	7.30	3.86	5.39	3.19	1924	886	1319	738
SPGMA 94021	6.48	6.40	5.18	4.51	1446	1482	1118	1041
Mean of female lines	8.57	5.57	5.04	2.70	1591	1259	1339	612
General mean	12.42	7.31	5.52	3.38	3165	1661	1509	761
Check(Shandaweel 6)	13.64	11.74	6.88	3.34	3766	2942	1635	858
R. L.S.D	1.24	0.86	0.75	0.64	235.6	222	531	520

2-Genetic parameters

Table (7) shows the genetic parameters of the reference population, which was the Egyptian sorghum line population, under two irrigation regimes and two conditions.

1-Green leaf area at flowering (GLA)

The additive gene effects contributed to GLA variance at flowering, which was apparently less than dominance gene effects, resulting in an additive / dominance ratio of 0.07, 0.01, 0.15 and 0.14 under normal and water stress conditions at Sohag and Assiut locations, respectively. These results suggest the important role of non-additive gene effects in the genetic system controlling GLA inheritance. Assuming, the absence of epistasis effects, the average degree of dominance was 5.20, 11.74, 3.69 and 3.82 under normal and water stress conditions at Sohag and Assiut location, respectively. These results are in harmony with those obtained by ***van Ooterom et al (1996)*** who reported that green leaf area at flowering showed complete dominance.The broad and narrow-sense heritability estimates for GLA were (96.2,29.5), (94.8, 7.5), (93.5, 43.8) and (91.8, 41.4) under normal and water stress conditions at Sohag and Assiut locations, respectively. These results indicate that selection for GLA under Assiut conditions would be more rewarding than under Sohag conditions. These results are in harmony with those obtained by ***Sankarapandian et al (1993)*** who recorded high heritability for green leaf area under normal and water stress at the vegetative, flowering and maturity phases. ***Viswanathan and Francis. (2002)*** reported that heritability for green leaf area at flowering was surprisingly high (0.70) under post rainy season.

2- Relative green leaf area duration (GLAD%)

The variance due to additive gene effects controlling relative green leaf area duration was less than that due to dominance gene effects. The additive dominance / ratio was 0.13, 0.08, 0.30 and 0.06 under normal and water stress conditions at Sohag and Assiut location, respectively. These results revealed the important role of dominant gene effects in the genetic system controlling relative GLAD% inheritance. This ioncluoion is also supported by over dominance of genes controlling relative GLAD% reflected in the average degree of dominance of 3.86, 5.15, 2.60 and 5.64 under normal and water stress conditions in Sohag and Assiut location, respectively. The above results are in harmony with those obtained by ***van Oosterom et al (1996)*** who reported that relative GLAD% was completely dominant under post-rainy season and partially dominant under simulated rainy season. Nevertheless, the very high average of dominance ratios suggest the possibility of epistatic effects.The broad and narrow-sense heritability for relative

GLAD% were (87.05, 38.79), (81.18, 25.32), (89.79, 57.42) and (81.46, 22.30) under normal and water stress conditions in Sohag and Assiut locations, respectively. These estimates suggest that future selection programs must be carried out under normal irrigation, since the narrow sense heritability estimates were high under this condition.

3- Absolute green leaf area (GLAD)

The additive / dominance ratio for this trait was 0.13, 0.09, 0.26 and 0.11 under normal and water stress condition at Sohag and Assiut locations, respectively. The average degree of dominance was 3.94, 4.82, 2.76 and 4.35 under normal and water stress at Sohag and Assiut locations, respectively. These results indicate that the variance due to additive gene effects controlling absolute GLAD was less than that due to dominance gene effects under all studied environments as well as the increased role of non-additive gene effects under water stress. These results are in harmony with those obtained by ***van Oosterom et al (1996)*** who reported that absolute GLAD showed over dominance under post rainy season and over dominant under simulated rainy season.The broad and narrow sense heritability estimates for absolute GLAD were (93.61, 40.81), (90.41, 30.77), (94.40, 57.81) and (91.63,35.53) under normal and water stress condition at Sohag and Assiut locations, respectively. It is clear that the average degree of dominance increases under water stress conditions for all studied traits, which means that the level of dominant gene action depends on the environment. These results are in harmony with those obtained by ***Walulu et al (1994)*** who reported that environment has a strong influence on the mode of expression of gene(s) controlling the stay-green trait in sorghum.Finally, the results indicate that the stay-green trait in sorghum is controlled by dominance gene which exhibit various levels of dominant gene action depending on the environment in which the materials are evaluated. However, the very high average degree of dominance imposes the question about the role of epistasis effects

Table7: Genetic components and the broado and narrow sense-hertibability of sorghum population in Egypt

Genetic Parameters	GLA at flowering				Relative green leaf area duration (GLAD%)			
	Sohag		Assiut		Sohag		Assiut	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Additive Variance	25532	5968	26593	23737	5716	1679	6407	1502
Dominance Variance	345739	411434	180779	173302	42675	22232	21639	23909
Add./Dom. Ratio	0.07	0.01	0.15	0.14	0.13	0.08	0.30	0.06
Av. degree of dom.	5.20	11.74	3.69	3.82	3.86	5.15	2.60	5.64
Broad h^2%	96.24	94.83	93.55	91.86	87.05	81.18	89.73	81.46
Narrow h^2%	29.55	7.59	43.86	41.44	38.79	25.32	57.42	22.30
	Absolut green leaf area duration(GLAD)				Leaf area retention			
	Sohag		Assiut		Sohag		Assiut	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Additive Variance	0.51	0.13	0.29	0.09	91467	58219	14898	2966
Dominance Variance	3.93	1.49	1.11	0.83	517109	2064191	63957	51029
Add./Dom. Ratio	0.13	0.09	0.26	0.11	0.18	0.03	0.23	0.06
Av.degree of dom.	3.94	4.82	2.76	4.35	3.36	8.42	2.93	5.87
Broad h^2%	93.61	90.41	94.40	91.63	89.76	23.96	88.39	89.36
Narrow h^2%	40.81	30.77	57.81	35.53	46.22	3.47	51.53	23.10

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4- Green leaf area retention (LAR)

The additive /dominance ratio was0.18, 0.03, 0.23 and 0.06 under normal and water stress at Sohag and Assiut locations, respectively. It was obvious that the contribution of additive variance decreased under water-stress conditions while the dominance variance increased. The average degree of dominance was3.36, 8.42, 2.93 and 5.87 under normal and water stress atSohag and Assiut locations, respectively. These results show the important role of dominance effects in the genetic system controlling LAR. ***Tenkouano et al, (1993)*** also reported that LAR was regulated by both dominant and recessive epistatic effects.The broad and narrow-sense heritability estimates for LAR were (89.76, 46.22), (23.96, 3.47), (88.39, 51.5) and (89.36, 23.10) under normal and water-stress at Sohag and Assiut locations, respectively. Apparently, the narrow sense-heritability estimates were higher under normal irrigation suggesting that selection for improving the stay-green trait in Sorghum is advisable under this condition.

Finally, it is important to note that our material was a random sample of grain sorghum lines so all their hybrids also represent a random sample of the hybrids population that can be arise from this line population which contain different gene combinations. The stay-green under favorable condition express the natural genetic system controlling stay-green. The estimates of stay-green and stay green components under unfavorable conditions result in confounding the effects beside the actual effects like abiotic stresses that motivate and accelerate senescence procedures and may be an evaluation of stay green stability. The previous results indicate that some genes controlling the stay green displayed opposite dominant effects (of positive and negative direction), and their expression interact significantly with environmental factors. Nevertheless, the comprehensive understanding of the stay-green trait needs more investigation on specific crosses to illuminate the additive gene effects and the interactions between alternative alleles at one locus and different genes allocated different sites as well as the interaction with environment factors. The ratios of additive/dominance variances of different stay green components indicate the predominana of dominance variance which is amplified under harsh conditions. The narrow-sense heritability of the stay-green trait and its components suggest that successful selection for this trait must be done under favorable conditions.

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سلوك ووراثة صفة بقاء النبات اخضر في ذرة الحبوب الرفيعة (سورجم ببيكلر ل.) تحت الري العادى والإجهاد المائي

إيمان محمد حسان* ، ميشيل فخري سابا*، **محمد عبد المنعم المرشدى، ** مسعد زكى الحفنى

** قسم المحاصيل-كلية الزراعة-جامعة أسيوط

* قسم بحوث الذرة الرفيعة-مركز البحوث الزراعية-القاهرة

يهدف البحث لمعرفة معرفة مدى وجود صفة بقاء النبات أخضر في التراكيب الوراثية المصرية في ذرة الحبوب الرفيعة ودراسة وراثة هذه الصفة تم اختيار 6 سلالات عقيمة ستيوبلازميا مع 6 سلالات معيدة للخصوبة تم اختيارها عشوائياً من التراكيب الوراثية المتوفرة وذلك لإنتاج 36 هجين قمي باستخدام طريقة السلالة × الكشاف 0 تم تقييم جميع التراكيب الوراثية (36 هجين +6اباء +6امهات+ صنف القياسي)تحت الري العادي والإجهاد المائي بعد الأزهار وذلك عن طريق منع الري في مرحلة ما قبل طرد النورات (booting stage) حتى الحصاد في موقعين أسيوط و سوهاج 0 تم قياس 4 صفات أساسية لبقاء النبات أخضر وهي المساحة الورقية الخضراء عند الأزهار(GLA) ، المساحة الورقية الخضراء الكلية الفعالة من مرحلة الأزهار وحتى الحصاد GLAD and (GLAD%)، المساحة الورقية الخضراء عند الحصاد (LAR)0 أظهرت جميع الصفات المدروسة نقص وانخفاض نتيجة للإجهاد المائي وكانت ظروف أسيوط أكثر إجهاداً نظراً للأراضي الرملية المستصلحة الفقيرة في العناصر الغذائية إضافة إلي زيادة نسبة الملوحة 0 وكنتيجة لمنع الري قبل طرد النورات فقد أدي ذلك لنقص المساحة الورقية الخضراء عند الأزهار 0 وقد أظهرت الآباء والأمهات والهجن فروق معنوية لجميع الصفات المدروسة 0 وقد أظهر تقسيم التباين الوراثي إلي مكونيه المضيف والغير مضيف أن صفة بقاء النبات أخضر يتحكم فيها فعل الجين الغير مضيف وكانت درجة السيادة أعلي تحت الظروف الاجهاد أوضحت 0 درجة التوريث في معناها الواسع والضيق أن الانتخاب لصفة بقاء النبات أخضر يكون أفضل تحت الظروف المثالية.