Effect of water stress on Leaf area, Relative water content and Stay-green habit of Iranian landraces *(Triticum aestivum L.)*under Irrigated, Restricted Irrigated and Rain-fed conditions

Abstract

Water stress is one of the major and challenging abiotic stress that affects the plant almost at all stages like tillering, booting, anthesis, grain formation, and grain filling.The present study aimed to investigate the effect of water stress on relative water content, leaf area and stay green habit of Iranian landraces along with commercial relevant checks under irrigated, restricted irrigated and rain-fed conditions.27 landraces were selected based on minimum reduction in vigor index as compared to control lines during preliminary screening experiment in the lab in which water stress induced by Polyethylene glycol (PEG6000).A field experiment was carried out at the experimental area of the Department of Plant Breeding & Genetics, Punjab Agricultural University,Ludhiana, Punjab during 2016-2017.The relative water content of Iranian landraces was calculated at the bolting stage according to the turgid weight by applying the equation of relative water content. Leaf area was recorded by leaf area meter and stay- green habit based ona 1-4 visual scale.Analysis of variance reveals that interaction among treatment and genotypes were significant for all the characters. Based onthe performance of Iranian landraces under restricted and rain-fed conditions,5 lines namelyIWA 8600397, IWA 8600841, 8606741, IWA 8606741 and Cltr 15395 were considered as water stress tolerant. ~~these are IWA 8600397, IWA 8600841, 8606741, IWA 8606741 and Cltr 15395~~.

Keywords:Iranian landraces, Leaf area,Relative water content, Stay-green habitandWaterstress

Introduction

Wheatis one of the most important cereal crop in the world in terms of the area ~~harvested~~, production and nutrition as it supplies 19% of calories and 21% of the protein than any other cereal crop (1).The demandfor wheat due to the rapid increase in population is expected to increase by 31% in 2050 as compared to 683 million tons consumed in 2008(5).Among the abiotic stresses, water stress and temperature severely affect the production of wheat (7) ~~During~~duringthe reproductive ~~stage,~~stage; drought stress causesa 70-80% loss in yield of the crop as well(13). Drought stress affects the growth of plants from seedling to full maturity ~~stage which~~stage, which~~results in the reduction of yield~~causes yield reduction (3).During water stress, there is a reduction in grain yield due to a decrease in the rate of photosynthesis and stem ~~reserves~~ reservoir(19). Persistence of green leaf during stress in wheat has a positive relationship with yield because 30-50% of total assimilates needed for grain filling used during

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photosynthesis. In wheat, stay-the green character of flag leaves plays a major role in providing resistance againstdrought stress (22).Leaves are the main photosynthetic organs in plants and under stress ~~conditions,~~conditions; there is a reduction in the growth of ~~leaf which~~leaf, which is mainly due to a decrease in water potential (23).Water stress reduced the leaf area, which affects the rate of photosynthesis in plants. The number of leaves per plant, leaf size, and leaf longevity decreased due to ashortage of water. During water stress, leaf growth is highly affected in wheat (18). Wheat genotypes that sustainflag leaves for a longer time, produced ~~better~~ higheryield in stress ~~conditions(~~conditions (14).

Water-use efficiency in plants is defined as the ratio between dry matter produced and consumed. Water-use efficiency during stress conditions in wheat was greater thanwell-watered conditions. It is increased due to the closure of stomata to reduce the rate of transpiration under stress ~~conditions which~~conditions that results in yield~~in the~~ reduction ~~of yield~~(1). Relative water content used as thebest ~~criteria which~~criteria, which indicate the amount of water absorbed and consumed by a plant throughtranspiration (12).reported that relative water content in wheat positively correlated with grain yield, biological yield, and harvest index of the plant. Leaf area and relative water content both are useful characters reflecting the overall water status of plants (10).The process of staying green or delay in senescence is known as a stay-green character in plants, duration of stay-green genotype, and harvest index is positively correlated with water use efficiency during grain development (8).Genotypes which have stay-green character contributed 30-50% of ~~photosynthates~~photosynthesis required during grain filling time (22).Wheat flag leaf had a positive correlation with yield under drought stress (24)~~therefore,~~therefore; stay- green character is an important selection trait, in breeding programs to improve the crop adaptation under water stress environment in sorghum and wheat (4). Stay-green should be considered as an important component in the genetic improvement of several crops to promote stress tolerance and enhanced yield grain (16).

The main objective of this work is to investigate the effect of water stress on leaf area, relative water content, and stay green habit of Iranian wheat landraces under water stress conditions.

Materials and Methods:

A field experiment was conducted during November 2016-17 at the Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana to evaluate theleaf area, relative water content, and stay-green habitof Iranian wheat landraces under water stress.27 lines were selected based onthe vigor index from the preliminary screening experiment. These lines showed minimum reduction as compared to control in all seedling parameters ~~(~~ germination percentage, coleoptile length, root length, shoot length root and shoot fresh and dry weight at 14%

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Polyethylene glycol (6000) treatment(11).These Iranian landraces were grown under irrigated, restricted ~~irrigated,~~irrigated and rain-fed conditions.Control treatment (Irrigated) was well watered throughout the growing period (five irrigations).Drought environment was created by withholding irrigation (two irrigations) and rain-fed condition (no irrigation).The experiment was carried out in RBD design with three treatments ~~with~~ andthree replications.Sowing was done in the last week of November 2016. Leaf area from 10 randomly selected plants from each ~~environment~~ treatment(irrigated, restricted irrigated and rain-fed) was measured by leaf meter (ADC Bio Scientifica Ltd.).Relative water content (RWC) was recorded at the booting stage of the plant,according to Siddique *et al*(21), where fresh weight from the flag leaves of Iranian landraces under irrigated, restricted irrigated and rain-fed conditions wererecorded. Turgid weight was obtained after soaking the leaves for 24 hours. Samples were dried for 72 hours in the oven at 60-62°C. Relative water content was calculated from the following equation:

RWC = [(fresh weight – dry weight) / (turgid weight – dry weight)] × 100

Stay- green Habit of foliage leaf based on visual using the 1-4 scale:

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1. <25% of foliar tissue showing green color
2. 25-50% of foliar tissue showing green color
3. 50-75% of foliar tissue showing green color
4. >75% of foliar tissue showing green color

Statistical analysis: The statistical analysis was carried out with the help of CPCS-1 software using RBD (Randomized block design) factorial.

Results and Discussions

ANOVA (Analysis of Variance)

Analysis of variance revealed was conducted. The mean square due to treatment, genotypes, and interaction between treatments and genotypes were significant for the characters i.e. leaf area, relative water content,and stay green habit at anthesis and 30 days after anthesis (Table 1).

Table 1:Analysis of the variance of Iranian wheat landraces along with 8 checks under Irrigated, Restricted-irrigated and Rain-fed conditions during 2016-2017

Mean Square of the Characters					
Source of variation	DF	LA	RWC	SGHA	SGH30
Rep	1	63.6	231.9	1.71	1.9
Treatment	2	74.4	888.05	0.44	0.99
Genotype	34	536.6	80.8	0.17	0.95
Trt* genotype	68	843.27*	213.08*	0.63*	0.14*
Error	104	12.77	5.032	0.20	0.77
Total	209				

Abbreviations: DF- Degree of freedom, LA- Leaf area, RWC- Relative Water Content, SGHA- Stay green habit at anthesis, SGH30-Stay green habit at 30 days after anthesis, * Significance at 5%

Leaf area ($cm^{2)}$

Flag leaf area plays an important role in wheat because the size of the leaf is positively related to the grain yield of the crop (15).Under water stress, there was a reduction in cell division due to a decrease in the turgor pressure of ~~cells which~~cells, which ultimately reduced ~~the~~ leaf area (17). The reduction in leaf area affects the photosynthetic activity of plants. The ~~decreased~~ reductionin leaf area and photosynthetic activity under drought stress reduced the ~~photosynthetic~~photosynthesis~~for~~of crops, which decreased the yield of plants. Leaf area plays an important role in plant development because it reflects the size of the assimilatory system.

In irrigated conditions, leaf area among plant genotypes varied between 160.5to 187.7 cm^2 with anaverage of 174.1cm^2 (Table 2).Among commercial checks, C-306 had maximum (194.5cm^2) whereas minimum leaf area was recorded in Gladius (170.5cm^2) (Table 5).Among Iranian lines, IWA 8606661 had a maximum (187.7cm^2) leaf area whereas the minimum leaf area was recorded in IWA 8606258 (160.5cm^2) (Table 5).

Under restricted-irrigated condition leaf area varied between145.0 to 184.0with a mean of 164.5 (Table 2). In commercial relevant checks, Bwl 5233 had maximum (187.0) whereas minimum leaf area was recorded ~~in PBW~~in PBW 660(153.7) (Table 5).Among Iranian lines, IWA8606741 showed the ~~had a~~maximum (184.0) whereas IWA8600091 ~~had~~ bear ~~a~~theminimum (145.0) leaf area (Table 5).

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In the rain-fed conditions, leaf area among plant genotypes varied between108.1 to 164.5 with an average of 136.3 (Table 2). Among commercial checks, C-518 had a maximum (168.3) whereas minimum leaf area recorded in PBW 175 (142.5) (Table 5). In Iranian lines, IWA 8606741 had the highest (164.5) while IWA 8606258 had the lowest (108.1) leaf area (Table 5).

Leaf area reduced due to loss of turgidity under water stress. Allahverdiyev *et al* (2) reported that leaf area in wheat cultivars due to limited surface area under water stress. A similar result was found by Gupta *et al* (9) in wheat, which is consistent with present studies.

Table 2: Ranges and mean value of leaf area of Iranian landraces and checks under Irrigated,Restricted irrigated and Rain-fed conditions

Leaf area				
Characters		**Irrigated**	**Restricted irrigated**	**Rain-fed**
Landraces	Min	160.5	145	108.1
	Max	187.7	184	164.5
	Mean	174.1	164.5	136.3
Mean value of checks	Gladius	170.5	157.8	151.8
	Bwl 5233	190.5	187	158.5
	C-306	194.5	181.5	160.5
	PBW660	178.8	153.7	145

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	C-518	180.5	178.6	168.3
	C-591	182.0	174.5	157.5
	C- 273	182.5	174	145.2
	PBW175	187.0	155	142.5

Table 3: Mean value of leaf area of Iranian landraces under Irrigated, Restricted irrigated and Rain-fed conditions

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Sr.No	Genotypes	Irrigated	Restricted	Rain-fed

			irrigated	
1	PETTERSON ML68-10	184.5	170.5	145.6
2	Cltr 15395	182	172	162.5
3	IWA 8600064	187	177.2	158.6
4	IWA 8600091	167.8	145	135.3
5	IWA 8600179	186	161.7	157.8
6	IWA 8600191	181.2	161	131.9
7	IWA 8600232	180	175.7	150.2
8	IWA 8600397	178.5	175.1	160
9	IWA 8600435	186.5	150.5	143.3
10	IWA 8600440	187.5	182	161.9
11	IWA 8600542	184.5	170.5	159.5
12	IWA 8600567	166.1	165	140
13	IWA 8600596	175.1	163	147.3
14	IWA 8600715	181.6	152.8	146
15	IWA 8600795	176	175.8	146
16	IWA 8600796	182.8	171.9	161.5
17	IWA 8600841	180.5	170.5	160.5
18	IWA 8600846	180.5	170.5	150.5
19	IWA 8600883	177.2	160.5	148.5
20	IWA 8606258	160.5	153	108.1
21	IWA 8606633	181.5	179	160.5
22	IWA 8606661	187.7	174.5	145
23	IWA 8606739	186.4	161.2	157
24	IWA 8606753	183.5	182.5	129.5
25	IWA 8606741	187.6	184	164.5
26	IWA 8607572	180	172.4	155
27	IWA 8607576	175.7	166	123.8
28	Gladius	170.5	157.8	151.8
29	Bwl 5233	190.5	187	158.5
30	C-306	194.5	181.5	160.5
31	PBW660	178.8	153.7	145
32	C-518	180.5	178.6	168.3
33	C-591	182	174.5	157.5
34	C- 273	182.5	174	145.2
35	PBW175	187	155	142.5
CD (5%)		**A- Treatment** **B-Genotypes** **A×B(Interaction)**	**7.09**	**1.199** **4.096**

Relative water content

Relative water content reduced ~~Under~~ under drought stress in wheat ~~relative water content reduced~~ which affects the yield of the crop.Schonfled *et al* (20) reported that cultivars having high relative water content are more resistant to drought stress. Abbate *et al* (1) found that water-use efficiency during stress conditions in wheat was greater than well-watered conditions**.** In irrigated condition relative water content among plant genotypes varied between 58.7to 35.3 with an average of 76.5 (Table 3). Among commercial checks, C-273 and C-306 had maximum (47.8) whereas minimum relative water content was recorded in PBW 175 (34.3) (Table 6). Among Iranian lines, IWA 8606661 had maximum (58.7) relative water content whereas minimum relative water content was recorded in IWA 8600232 (35.3) (Table 6). In restricted- irrigated condition relative water content among plant genotypes varied between 28.1 to 56.1with an average of 42.1 (Table 3). Among commercial checks,C-306 and C-273 had maximum (40.3) whereas minimum leaf area recorded in PBW175 (31.1) (Table 6). Among Iranian lines, IWA 8600091 had maximum (56.1) whereas minimum relative water content was recorded in IWA 8600440 (28.1) (Table 6).In rain-fed condition relative water content among plant genotypes varied between 22.8 to 54.3with an average of~~38.5 (~~38.5 (Table 3). Amongcommercial checks,C-518 had a maximum (34.4) whereas minimum leaf area recorded in PBW175(28.0) (Table 6). Among Iranian lines, IWA 8600091 had maximum (54.3) whereas minimum relative water content was recorded in IWA 860091 (22.8) (Table 6).

Table 4: Ranges and mean value of Relative water content of Iranian landraces and checks under Irrigated,Restricted Irrigated and Rain-fed conditions

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Relative water Content				
Characters		**Irrigated**	**Restricted irrigated**	**Rain-fed**
Landraces	Min	58.7	28.1	22.8
	Max	35.3	56.1	54.3
	Mean	76.5	42.1	38.5
Mean value of checks	Gladius	45.4	34.4	28
	Bwl 5233	39.5	30	29.65
	C-306	47.8	40.3	32.8
	PBW660	35.5	32.4	29.45
	C-518	45.4	39.9	34.4
	C-591	39.5	34.5	29.65
	C- 273	47.8	40.3	32.8
	PBW175	34.35	31.1	28

Table 5:Mean value of Relative water content of Iranian landraces under Irrigated,Restricted irrigated and Rain-fedconditions

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Sr.No	Genotypes	Irrigated	Restricted irrigated	Rain-fed
1	PETTERSON ML68-10	52.8	46.0	39.3
2	Cltr 15395	57.9	54.8	51.8
3	IWA 8600064	45.7	41.7	37.7
4	IWA 8600091	58	56.1	54.3
5	IWA 8600179	48.2	43.7	39.3
6	IWA 8600191	50.7	36.7	22.85
7	IWA 8600232	35.3	32.4	29.5
8	IWA 8600397	45.3	39.7	34.2
9	IWA 8600435	39.5	34.5	29.6
10	IWA 8600440	47.8	28.1	32.7
11	IWA 8600542	53	50.3	47.7
12	IWA 8600567	38.2	36.3	34.55
13	IWA 8600596	53.15	46.2	39.4
14	IWA 8600715	45.4	41.7	38
15	IWA 8600795	54	47.7	41.4
16	IWA 8600796	54.2	50.8	43
17	IWA 8600841	54.45	48	41.55
18	IWA 8600846	47.1	45.0	42.9
19	IWA 8600883	53.0	49.3	45.5
20	IWA 8606258	57.2	50.2	43.3
21	IWA 8606633	53.1	45.5	38.0
22	IWA 8606661	58.7	50.9	43.0
23	IWA 8606739	47.0	45.1	43.1
24	IWA 8606753	53	50.5	48
25	IWA 8606741	53	50.5	48
26	IWA 8607572	50.5	46.7	43
27	IWA 8607576	35.5	34.9	34.4
28	Gladius	45.4	34.4	28
29	Bwl 5233	39.5	30	29.6
30	C-306	47.8	40.3	32.8
31	PBW660	35.5	32.4	29.4
32	C-518	45.4	39.9	34.4
33	C-591	39.5	34.5	29.6
34	C- 273	47.8	40.3	32.8
35	PBW175	34.3	31.1	28
(CD 5%)		**A- Treatment** **B- Genotypes** **A×B(Interaction)**		**0.752** **2.57** **4.45**

Stay-green habit at anthesis and 30 days after anthesis

visual scale for ~~S~~stay- green habit at anthesis under irrigated condition ~~visual scale of~~ was recorded 3 ~~was recorded~~ among Iranian landraces and commercial check. In irrigated condition stay- green habit at anthesis among plant genotypes varied between 3.0

to 3.0 with an average of 3 (Table 4).Stay -green habit under restricted condition among plant genotypes varied between 1.5to 2.5 with an average of2 (Table 4). Under restricted irrigated most of the Iranian landraces and commercial checks lie on the visual scale of 2, except IWA 8600064and IWA 8601911. Under Rain-fed condition among plant genotypes varied between 2.5to 3.0 with an average of 2.7 (Table 4). Under the rain-fed condition, a visual scale of 2 and 2.5 was recorded among most of the Iranian landraces (Table 7). Among commercial checks, a visual scale of 2.5 where 50-75% of foliar tissue showing green color was recorded**.**

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Stay- green habit after 30 days at anthesis under irrigated conditionamong plant genotypes varied between 1.9 to 2.6 with an average of 2.3 and under restricted condition ranged between2.0-2.7 with an average of 2.3 (Table 5). Under rain-fed condition staygreen habit after 30 days anthesis among plant genotypes lie in the range of 2.0-2.7 with a mean of 2.3 (Table 5). Stay- greenhabitafter 30 days anthesis among Iranian landraces and commercial checks under irrigated, restricted irrigated and rain-fed lie on the visual scale of 2 where 25-50% of foliar tissue showing green color (Table 8).

Table 6: Ranges and mean value of Stay -green ~~habitat~~habitat anthesis of Iranian landraces and checks under Irrigated, Restricted Irrigatedand Rain-fed conditions

Stay- green habit at anthesis				
Characters		**Irrigated**	**Restricted irrigated**	**Rain-fed**
Landraces	Min	3	1.5	2.5
	Max	3	2.5	3
	Mean	3	2	2.7
Mean value of checks	Gladius	3	2	2.5
	Bwl5233	3	2	2.5
	C-306	3	2.5	2.7
	PBW660	3	2	2.5
	C-518	3	2	2.5
	C-591	3	2	2.5

	C- 273	3	2	2.5
	PBW175	3	2.5	2.7

Table 7: Ranges and mean value of of Stay green habit 30 days after anthesis of Iranian landraces and checks under Irrigated, Restricted Irrigated and Rain-fed conditions

Stay green habit 30 days after anthesis				
Characters		**Irrigated**	**Restricted irrigated**	**Rain-fed**
Landraces	Min	1.9	2	2
	Max	2.6	2.7	2.7
	Mean	2.3	2.3	2.3
Mean value of checks	Gladius	2.3	2.4	2.3
	Bwl5233	2.6	2.7	2.7
	C-306	2.3	2.4	2.3
	PBW660	2.3	2.4	2.3
	C-518	2.3	2.4	2.3
	C-591	2.3	2.4	2.3
	C- 273	2.6	2.7	2.7
	PBW175	2.5	2.4	2.4

Table 8:Mean value of Stay green habit at anthesis under Irrigated,Restricted irrigatedand Rain-fed conditions

Sr.No	Genotypes	Irrigated	Restricted irrigated	Rain-fed
1	PETTERSON ML68-10	3	2	2.5
2	Cltr 15395	3	2	2.5
3	IWA 8600064	3	1.5	2.25
4	IWA 8600091	3	2	2.5
5	IWA 8600179	3	2.5	2.75
6	IWA 8600191	3	1.5	2.25
7	IWA 8600232	3	3	3
8	IWA 8600397	3	3	3
9	IWA 8600435	3	2	2.5

10	IWA 8600440	3	2	2.5
11	IWA 8600542	3	2	2.5
12	IWA 8600567	3	2	2.5
13	IWA 8600596	3	2	2.5
14	IWA 8600715	3	2.5	2.75
15	IWA 8600795	3	2	2.5
16	IWA 8600796	3	2	2.5
17	IWA 8600841	3	2.5	2.75
18	IWA 8600846	3	2	2.5
19	IWA 8600883	3	2.5	2.75
20	IWA 8606258	3	2.5	2.75
21	IWA 8606633	3	2	2.5
22	IWA 8606661	3	2.5	2.75
23	IWA 8606739	3	2	2.5
24	IWA 8606753	3	2	2.5
25	IWA 8606741	3	2	2.5
26	IWA 8607572	3	2	2.5
27	IWA 8607576	3	2	2.5
28	Gladius	3	2	2.5
29	Bwl 5233	3	2	2.5
30	C-306	3	2.5	2.75
31	PBW660	3	2	2.5
32	C-518	3	2	2.5
33	C-591	3	2	2.5
34	C- 273	3	2	2.5
35	PBW175	3	2.5	2.75
CD (5%)		**A- (Treatment)** **B-(Genotypes)** **A×B (Interaction)**		**NS** **NS** **0.908**

Table 9:Mean value of stay green habitat 30 days after anthesisunder Irrigated, Restricted irrigated and Rain-fed conditions

Sr.No	Genotypes	Irrigated	Restricted irrigated	Rain-fed
1	PETTERSON ML68-10	2.3	2.4	2.3
2	Cltr 15395	1.9	2.1	2.0
3	IWA 8600064	2.3	2.4	2.3
4	IWA 8600091	2.6	2.7	2.7
5	IWA 8600179	1.9	2.1	2.0
6	IWA 8600191	2.5	2.0	2.5
7	IWA 8600232	2.5	2.5	2.0
8	IWA 8600397	2.3	2.4	2.3
9	IWA 8600435	2.3	2.4	2.3
10	IWA 8600440	2.3	2.4	2.3
11	IWA 8600542	2.3	2.4	2.3
12	IWA 8600567	2.3	2.4	2.3
13	IWA 8600596	2.6	2.7	2.7
14	IWA 8600715	2.3	2.4	2.3
15	IWA 8600795	2.3	2.4	2.3
16	IWA 8600796	2.6	2.7	2.7
17	IWA 8600841	2.3	2.4	2.3
18	IWA 8600846	2.6	2.7	2.7
19	IWA 8600883	2.6	2.7	2.7
20	IWA 8606258	2.3	2.4	2.3
21	IWA 8606633	2.6	2.7	2.7
22	IWA 8606661	2.3	2.4	2.3
23	IWA 8606739	2.3	2.4	2.3
24	IWA 8606753	2.3	2.4	2.3
25	IWA 8606741	2.3	2.4	2.3
26	IWA 8607572	2.3	2.4	2.3
27	IWA 8607576	2.3	2.4	2.3
28	Gladius	2.3	2.4	2.3
29	Bwl 5233	2.6	2.7	2.7
30	C-306	2.3	2.4	2.3
31	PBW660	2.3	2.4	2.3

32	C-518	2.3	2.4	2.3
33	C-591	2.3	2.4	2.3
34	C- 273	2.6	2.7	2.7
35	PBW175	2.5	2.4	2.4
CD (5%)		**A- (Treatment)** **B- (Genotypes)** **A×B (Interaction)**	**NS** **NS** **0.78**	

Conclusion

Generally from the present study, it is concluded that there is a reduction in leaf area, relative water content and stay-green habit of Iranian landraces under water stress conditions i.e. under restricted irrigated and rain-fed conditions. Leaf area decreases due to a reduction in turgor pressure of cell which ultimately reduces the leaf area which affects the rate of photosynthesis and yield of the crop.Relative water content among Iranian landraces under irrigated condition is more than that of under restricted irrigated and rain-fed condition due to closure ~~od~~ of~~stomata which~~stomata, which increase the transpiration rate in the crop. Genotypes having to stay- green character contributes ~~photosynthates~~ assimilatesneeded during the filling time.During drought stress, stay- green character among landraces under restricted irrigated and rain-fed condition reduced only 50 % of foliar tissue shows the green color as compared to irrigated condition.

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