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ORIGINAL PAPER

Characterization of some physiological traits of some bread wheat (*Triticum aestivum*) landraces for drought tolerance at late developmental stages

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Abstract
The present research was conducted to investigate some physiological traits of 22 bread wheat landraces as well as five registered cultivars under irrigated and late drought stress. In this study, significant differences were obtained between landraces in the investigated physiological traits generally and the responses of cultivars changed to years and applications. TGB 003232, TR 63581 and TGB 000534 landraces showed higher values than the average of registered cultivars in leaf relative water content under late drought stress conditions. According to rank analysis, Dağdaş 94, TGB 003232 and Müfitbey cultivars became prominent in drought tolerance at late developmental stages. In the photosystem II (PS II) maximum energy efficiency (F_v/F_m) value used to determine the drought tolerance of the genotypes, the bread wheat landrace Çalı basıran became prominent in all three stages. According to the results obtained, it is important to use landraces as a gene source in breeding studies in the physiological traits investigated.

Keywords Canopy · Chlorophyll fluorescence · Drought · Relative water content · Wheat landraces

Introduction

Wheat is grown in large areas in the world and Turkey because it is easy in sowing, care, harvest, transportation and storage. Due to its importance in human nutrition, it is important to increase yield, grain quality and stress tolerance of wheat. In the studies to be carried out in this direction, the biggest impact for the breeder is the plant gene sources (Sehirali and Ozgen 2012). Turkey is rich in animal and plant diversity as it has different ecological regions and as geographical and climatic is in a suitable location. Turkey, where wheat was first cultivated and one of the most important gene centers, has richness and diversity of local varieties that can be used directly or indirectly in wheat breeding studies. Landraces (village cultivars) are a group of individuals with similar appearances that survive under the pressure of natural and artificial selection, suitable for local palate, in the mostly population characteristics, which have a broad genetic basis (Ozberk et al. 2016).

Drought is an abiotic stress factor that limits the grain yield of wheat, which is usually produced in dry agricultural areas and causes serious problems in many parts of the world. Irregular distribution and insufficient rainfall in the wheat-growing season cause decreases in yield (Ozturk and Korkut 2018). Severity of drought on plants shows a change depending on developmental stages of wheat (Gupta et al. 2001).

Physiological traits are important factors used in determining drought tolerance in plants. Some physiological traits are suggested as selection criteria in breeding programs to improve drought tolerance (Kumar et al. 2012; Ozturk and Aydin 2017; Ozdemir Dirik 2020). It has been reported that stomatal conductivity, photosynthesis, transpiration rate and leaf relative water content decrease in plants exposed to drought stress (Monneveux et al. 2005; Anjum et al. 2011; Jamali et al. 2020). Leaf relative water content is the ratio to the total water content they can carry of the water contained in the leaves at the time of sampling

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(Taner 2011). It has been reported that the leaf relative water content is a more important indicator of plant water status as to other water potential parameters under drought stress conditions and is closely related to cell volume, which can reflect the balance between transpiration rate and water supply to the leaf (Dhanda and Sethi 1998).

Another physiological characteristic used in determining tolerant genotypes to drought in wheat is the canopy temperature difference, which is calculated as the difference between air temperature and canopy temperature. Canopy temperature difference can vary according to many factors such as genotypic characteristics, environmental conditions (Saygili 2019), ambient temperature, plant development stage, soil water status, wind speed, light intensity, relative humidity and cloudiness. For canopy temperature, it has been reported that it may not be healthy to compare the results of different studies and even of the results of the same study from different years and locations (Ozturk and Aydin 2014).

It has been stated that the light energy retained by chlorophyll molecules in the leaf can either be used in photosynthesis, dissipated as heat or reflected as light, and it is a feature used in measuring the photosynthetic performance of plants (Maxwell and Johnson 2000). Chlorophyll fluorescence parameters such as initial fluorescence (F_0), maximum fluorescence (F_m), variable fluorescence ($F_v = F_m - F_0$), photosystem II (PS II) maximum energy efficiency (F_v/F_m) give information about the degree of use of light energy and the degree of damage due to excessive light (Maxwell and Johnson 2000). Chlorophyll fluorescence parameters are commonly used in investigating the response to drought stress of genotypes (Ozturk and Aydin 2017) and can be used as a selection criterion for drought tolerance (Guo et al. 2008).

This study was carried out under irrigated and late drought stress with some bread wheat landraces in Tokat-Kazova conditions. It aimed to determine the responses of these cultivars to drought and to reveal the evaluation possibilities of the prominent cultivars in breeding studies based on their physiological characteristics.

Materials and methods

The trials were carried out in Tokat-Kazova conditions (40° 18′ north latitude and 36° 34′ east longitude, 623 m altitude) in the Middle Black Sea Region, in the 2017–2018 and 2018–2019 growing seasons, in the trial areas of Tokat Gaziosmanpasa University Agricultural Application and Research Center. The trails were conducted during months from November to June in each year. Some climatic data belonged to research growing seasons and long term of the trial area are given in Table 1, and the soil analysis results of the trial areas are given in Table 2. In the research, 22 bread wheat landraces collected from Tokat, Amasya and Corum provinces and protected in gene banks and provided from farmers in Tokat, as standard, Ozturk and Aydin (2014) according to the results obtained from their studies with bread wheat varieties, Gün 91, Müfitbey and Dağdaş 94 which are drought tolerant at late developmental stages, Bezostaja 1 and Aldane registered bread wheat varieties, whose drought sensitivity was determined, were used (Table 3).

The research was established in two separate trials (irrigated and late drought stress conditions) according to the random blocks trial design with 3 replications. Sowing was carried out manually at a distance of 20 cm row spacing, and sowing rate was arranged to 500 viable seeds per m^2

Table 1 Climatic data during the growing seasons and the average of long years (1960–2016) of Tokat province*

Climatic factors	Total precipitation (mm)			Average temperature (°C)			Average relative humidity (%)		
Months	2017–18	2018–19	Average of long years	2017–18	2018–19	Average of long years	2017–18	2018–19	Average of long years
November	42.6	8.2	44.1	7.7	9.2	7.9	68.0	73.3	70.1
December	49.3	49.4	46.6	5.5	4.9	3.9	72.8	80.7	71.3
January	33.4	71.6	40.3	5.1	2.2	1.8	66.8	76.5	69.1
February	15.4	14.7	34.0	8.3	5.9	3.5	62.0	67.0	64.7
March	79.7	36.8	40.7	11.9	7.2	7.4	58.4	61.8	60.6
April	4.5	63.5	55.3	14.9	11.5	12.5	46.4	65.2	59.1
May	59.1	49.1	58.5	18.5	19.1	16.5	60.9	59.7	60.7
June	41.5	26.2	38.3	22.0	23.1	19.9	55.0	63.4	59.0
July	7.2	16.9	11.1	24.2	21.9	22.3	52.7	59.6	56.9
Total	332.7	336.4	368.9						
Average				13.1	11.7	10.6	60.3	67.5	63.5

*Tokat Meteorological Station Directorate (2019)

Table 2 Physical and chemical properties of soils used in the two growing seasons

	Texture class	Organic matter (%)	Total salt (%)	Soil reaction (pH)	Lime ($CaCO_3$) (%)	P_2O_5 (kg da^{-1})	K_2O (kg da^{-1})
2017–18*	Clay-Loamy	1.00	0.022	8.1	20.60	5.68	157.70
2018–19**	Clay-Loamy	1.73	0.015	8.5	7.47	6.98	41.08

*Middle Black Sea Transitional Zone Agricultural Research Institute, Tokat (2017)

**Tokat Gaziosmanpasa University Scientific Research Projects (2018)

Table 3 Source of the studied wheat landraces

Cultivar	Provinces	Organizations from which it is supplied
TGB 003247	Corum	Field crops central research institute
TGB 000543	Corum	Field crops central research institute
TGB 003249	Corum	Field crops central research institute
TGB 000526	Corum	Field crops central research institute
TGB 003232	Corum	Field crops central research institute
TGB 000534	Corum	Field crops central research institute
TGB 000521	Corum	Field crops central research institute
TGB 003246	Corum	Field crops central research institute
TGB 003248	Corum	Field crops central research institute
TR 48371	Tokat	Aegean agricultural research institute
TR 37373	Corum	Aegean agricultural research institute
TR 63501	Tokat	Aegean agricultural research institute
TR 44433	Tokat	Aegean agricultural research institute
TR 63497	Tokat	Aegean agricultural research institute
TR 63581	Amasya	Aegean agricultural research institute
TR 63575	Amasya	Aegean agricultural research institute
Ak sunteri	Tokat	Tokat directorate of provincial Agri. and forestry
Dimenit	Tokat	Tokat directorate of provincial Agri. and forestry
Örmece	Tokat	Tokat directorate of provincial Agri. and forestry
Çam buğdayı	Tokat	Tokat directorate of provincial Agri. and forestry
Zerun	Tokat	Tokat directorate of provincial Agri. and forestry
Çalı basıran	Tokat	Tokat directorate of provincial Agri. and forestry
Aldane	–	Trakya agricultural research institute
Bezostaja 1	–	Transitional zone agricultural research institute
Müfitbey	–	Transitional zone agricultural research institute
Gün 91	–	Field crops central research institute
Dağdaş 94	–	Bahri Dağdaş international agricultural research institute

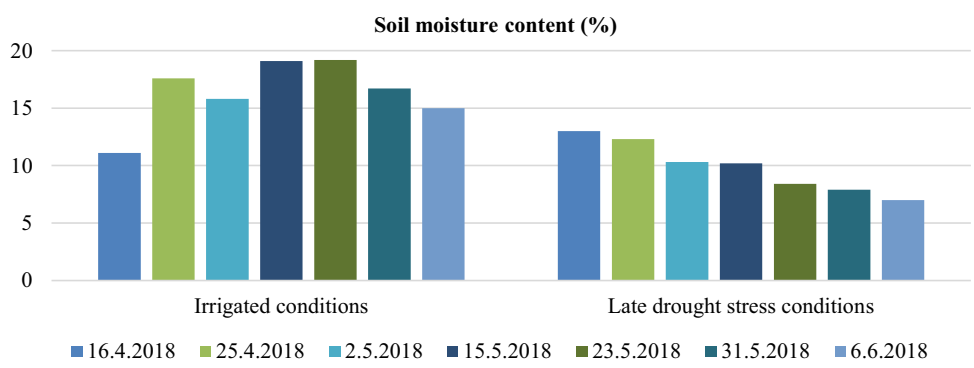


Fig. 1 Soil moisture contents of the trial areas under irrigated and late drought stress conditions in the 2017–2018 growing seasons (%)

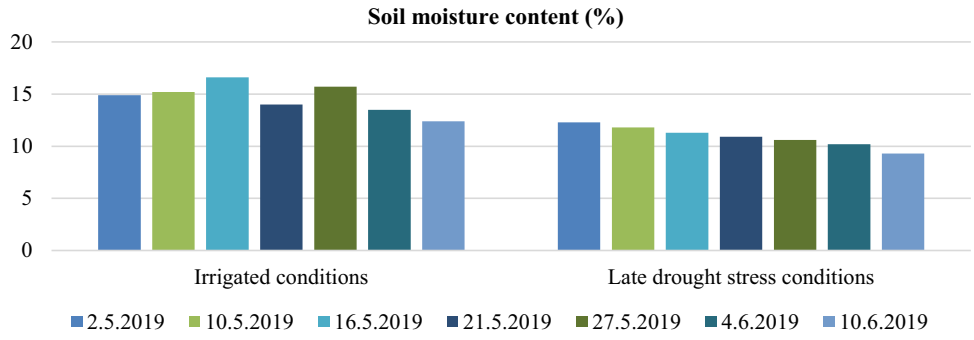


Fig. 2 Soil moisture contents of the trial areas under irrigated and late drought stress conditions in the 2018–2019 growing seasons (%)

Table 4 Leaf relative water contents of bread wheat cultivars grown under irrigated and late drought stress conditions

Cultivar	Irrigated conditions						Late drought stress conditions					
	2017–2018		2018–2019		Average of two seasons		2017–2018		2018–2019		Average of two seasons	
TGB 003247	86.3	ns	78.1	e-ı**	82.2	b–e**	76.2	b–e*	81.1	abc**	78.7	a–d**
TR 48371	88.2		80.7	a–e	84.4	ab	77.7	a–d	78.9	abc	78.3	a–d
TGB 003246	86.1		79.1	c–g	82.6	a–e	74.6	cde	79.1	abc	76.9	b–f
TR 44433	86.7		77.6	ghı	82.1	b–e	76.5	b–e	76.8	a–d	76.7	b–g
TGB 003232	86.7		79.4	b–g	83.1	a–d	78.0	abc	82.3	a	80.2	ab
TR 63581	86.7		80.0	b–g	83.4	a–d	78.1	abc	80.6	abc	79.4	abc
TR 37373	87.0		81.4	abc	84.2	abc	77.0	b–e	78.1	a–d	77.5	b–e
TGB 003249	86.5		77.5	ghi	82.0	b–e	76.7	b–e	78.5	a–d	77.6	bcd
TR 63501	85.8		80.6	a–f	83.2	a–d	74.4	cde	78.2	a–d	76.3	c–g
TR 63575	86.7		78.7	c-h	82.7	a–e	73.8	de	75.9	cde	74.8	d-g
TGB 000534	86.2		78.6	d-h	82.4	a–e	78.8	ab	80.0	abc	79.4	abc
TR 63497	85.0		80.7	a–e	82.8	a–e	75.6	b–e	77.8	a–d	76.7	b–g
TGB 003248	85.3		80.6	a–e	83.0	a–d	75.6	b–e	76.4	bcd	76.0	c–g
TGB 000543	85.4		75.7	ı	80.6	e	72.9	e	77.0	a–d	75.0	d-g
TGB 000526	86.5		79.3	c–g	82.9	a–e	76.1	b–e	80.3	abc	78.2	a–d
TGB 000521	86.7		76.1	hı	81.4	de	75.3	b–e	70.8	ef	73.0	g
Çam buğdayı	85.5		79.8	b–g	82.7	a–e	74.5	cde	72.9	def	73.7	fg
Çalı basıran	85.1		77.9	f-ı	81.5	de	76.2	b–e	75.4	c-f	75.8	c–g
Ak sunteri	86.0		81.2	a–d	83.6	a–d	76.7	b–e	78.5	a–d	77.6	bcd
Örmece	84.4		81.1	a–d	82.8	a–e	75.3	b–e	76.3	bcd	75.8	c–g
Dimenit	85.0		78.7	c-h	81.9	cde	75.4	b–e	77.6	a–d	76.5	b–g
Zerun	86.9		80.8	a–e	83.9	a–d	77.0	b–e	70.5	f	73.7	efg
Landrace mean	86.1		79.3		82.7		76.0		77.4		76.7	
Dağdaş 94	86.6		79.4	b–g	83.0	a–d	77.1	bcd	77.2	a–d	77.1	b–f
Müfitbey	86.0		80.0	b–g	83.0	a–d	81.2	a	81.7	ab	81.5	a
Gün 91	86.6		82.8	a	84.7	a	76.1	b–e	79.7	abc	77.9	a–d
Aldane	85.3		82.0	ab	83.7	a–d	77.3	bcd	81.7	ab	79.5	abc
Bezostaja 1	84.5		80.6	a–f	82.6	a–e	75.2	b–e	79.2	abc	77.2	b–f
Standard cultivar mean	85.8		81.0		83.4		77.4		79.9		78.7	
General mean	86.1 a**		79.6 b		82.9		76.3		77.9		77.1	
C.V. (%)	1.82		1.34		1.62		2.70		2.83		2.77	

*, **There is no difference according to the significance level of 5% and 1%, respectively, between the means in the same letter group. C.V.: coefficient of variation

ns Not significant

according to the results of the seed viability test. The plots consisted of two rows, of two-meter length and no spaces left between them. According to the results of soil analysis, fertilization was made at a rate of 100 kg N and 60 kg P_2O_5 per hectare to trials. Half of the nitrogen and all of the phosphorus were given with sowing; the second half of nitrogen was given at the stem elongation stage. Weed control was carried out with a herbicide containing 2, 4-D effective substance in all trials. In addition, spraying was carried out with fungicide of Boscalid and Kresoxim-methyl effective substance when beginning of powdery mildew disease is observed in the plots. The average volume weight of the 0–60 cm depth of the trial soil, the field capacity and they could hold by weight at permanent wilting point the moisture contents was determined. Moisture content of soils at a depth of 60 cm was determined by gravimetric method, starting from beginning of jointing, until the date of physiological maturity (Comert and Oztekin 2016). The soil moisture contents of the experiment areas are given in Figs. 1 and 2.

In the experiments carried out under irrigated conditions, when approximately 50% of the suitable water in the soil was consumed according to the determined moisture content, all plots were irrigated with drip irrigation method on April 19, 2018, and May 4, 2018, in the first year, and on May 23, 2019, and June 6, 2019, in the second year. In

Table 5 Canopy temperature differences at anthesis stage of bread wheat cultivars grown under irrigated and late drought stress conditions

Cultivar	Irrigated conditions						Late drought stress conditions					
	2017–2018		2018–2019		Average of two seasons		2017–2018		2018–2019		Average of two seasons	
TGB 003247	5.88	lm**	6.56	a–e**	6.23	cd**	3.90	ghı**	6.63	a–e**	5.27	b–e**
TR 48371	6.65	g–j	5.90	a–g	6.28	bcd	4.03	e–h	6.93	abc	5.48	bcd
TGB 003246	6.82	fgh	7.17	a	6.99	ab	4.17	c-f	6.37	a-h	5.27	b–e
TR 44433	6.77	fgh	5.67	b–g	6.22	cd	3.72	ıjk	6.20	a-h	4.96	c–g
TGB 003232	6.37	ıjk	4.70	fg	5.53	e	3.88	hı	6.37	a-h	5.13	b–f
TR 63581	7.27	de	5.27	efg	6.27	bcd	3.80	hıj	5.77	c-h	4.78	efg
TR 37373	5.68	m	6.87	abc	6.28	bcd	3.72	ıjk	5.17	h	4.44	g
TGB 003249	5.25	n	5.77	a–g	5.51	e	4.38	bc	5.70	d-h	5.04	c-f
TR 63501	7.27	de	6.13	a–f	6.70	abc	3.95	fgh	5.60	e–h	4.78	efg
TR 63575	8.55	a	4.67	g	6.61	abc	4.52	b	6.23	a-h	5.38	b–e
TGB 000534	7.77	bc	5.17	efg	6.47	abc	4.50	b	5.27	gh	4.88	d-g
TR 63497	7.07	ef	7.10	ab	7.08	a	4.38	bc	6.03	b-h	5.21	b–f
TGB 003248	7.35	de	5.47	c–g	6.41	a–d	3.53	k	6.87	a–d	5.20	b–f
TGB 000543	6.10	kl	6.63	a–e	6.37	a–d	4.20	cde	5.37	fgh	4.78	efg
TGB 000526	6.68	ghı	6.80	a–d	6.74	abc	3.65	jk	6.83	a–d	5.24	b–f
TGB 000521	6.32	jk	5.87	a–g	6.09	cde	4.83	a	6.20	a-h	5.52	bc
Çam buğdayı	7.48	cd	5.40	d-g	6.44	abc	4.33	bcd	6.50	a–f	5.42	bcd
Çalı basıran	6.37	ıjk	6.17	a–e	6.27	bcd	3.92	ghı	7.00	ab	5.46	bcd
Ak sunteri	5.35	n	5.70	b–g	5.53	e	3.89	hı	5.40	fgh	4.65	fg
Örmece	7.48	cd	6.07	a–g	6.78	abc	4.17	c-f	5.83	b-h	5.00	c–g
Dimenit	7.98	b	5.27	efg	6.63	abc	4.88	a	5.93	b-h	5.41	bcd
Zerun	6.77	fgh	6.00	a–g	6.38	a–d	4.38	bc	7.00	ab	5.69	ab
Landrace mean	6.78		5.93		6.36		4.12		6.15		5.14	
Dağdaş 94	6.87	fg	5.70	b–g	6.28	bcd	4.02	e–h	6.40	a–g	5.21	b–f
Müfitbey	6.85	fg	5.87	a–g	6.36	bcd	4.30	bcd	6.40	a–g	5.35	b–e
Gün 91	6.50	hıj	5.77	a–g	6.13	cde	4.82	a	7.40	a	6.11	a
Aldane	5.90	lm	5.50	c–g	5.70	de	3.70	ıjk	6.97	abc	5.33	b–e
Bezostaja 1	6.65	g–j	5.90	a–g	6.28	bcd	4.12	d-g	6.20	a-h	5.16	b–f
Standard cultivar mean	6.55		5.75		6.15		4.19		6.67		5.43	
General mean	6.74 a**		5.89 b		6.32		4.14 b		6.24 a**		5.19	
C.V. (%)	2.02		9.46		6.42		2.33		7.44		6.46	

**There is no difference according to the significance level of 1% between the means in the same letter group. C.V.: coefficient of variation

Table 6 Canopy temperature differences at 15 days post-anthesis of bread wheat cultivars grown under irrigated and late drought stress conditions

Cultivar	Irrigated conditions						Late drought stress conditions					
	2017–2018		2018–2019		Average of two seasons		2017–2018		2018–2019		Average of two seasons	
TGB 003247	9.70	abc**	6.97	a–d**	8.33	ab**	5.54	e-ı**	6.90	a**	6.22	a–e**
TR 48371	8.57	abc	6.70	a–e	7.63	ab	6.95	a–d	6.10	a–e	6.53	a–d
TGB 003246	9.85	abc	7.17	a–d	8.51	ab	5.63	e-ı	5.67	a–e	5.65	d-j
TR 44433	7.10	c	7.40	abc	7.25	ab	5.58	e-ı	4.80	de	5.19	f-j
TGB 003232	9.52	abc	6.50	b–e	8.01	ab	6.17	b-h	6.03	a–e	6.10	a–f
TR 63581	9.47	abc	7.33	abc	8.40	ab	4.88	hıj	5.13	b–e	5.01	hıj
TR 37373	9.38	abc	6.27	cde	7.83	ab	6.17	b-h	6.07	a–e	6.12	a–f
TGB 003249	8.75	abc	7.10	a–d	7.93	ab	4.43	ıj	5.73	a–e	5.08	g–j
TR 63501	8.22	abc	7.63	ab	7.93	ab	5.90	c-h	4.73	e	5.32	e-j
TR 63575	11.43	a	5.70	e	8.57	ab	5.27	f-j	6.13	a–d	5.70	d-j
TGB 000534	8.18	bc	6.70	a–e	7.44	ab	5.68	d-ı	6.33	abc	6.01	b–f
TR 63497	7.05	c	7.30	abc	7.18	ab	7.58	a	6.40	ab	6.99	a
TGB 003248	6.95	c	6.97	a–d	6.96	b	6.46	a–f	6.43	ab	6.45	a–d
TGB 000543	7.72	bc	7.47	abc	7.59	ab	6.25	b–g	6.10	a–e	6.18	a–e
TGB 000526	8.30	abc	7.80	a	8.05	ab	5.58	e-ı	6.27	abc	5.92	c-h
TGB 000521	7.68	bc	6.57	b–e	7.12	ab	7.65	a	6.17	a–d	6.91	ab
Çam buğdayı	10.55	ab	6.57	b–e	8.56	ab	7.07	abc	6.57	a	6.82	abc
Çalı basıran	7.37	bc	7.43	abc	7.40	ab	5.99	c-h	5.70	a–e	5.84	d-ı
Ak sunteri	8.87	abc	6.03	de	7.45	ab	5.45	e-ı	6.67	a	6.06	a–f
Örmece	7.45	bc	6.73	a–e	7.09	ab	6.69	a–e	6.37	ab	6.53	a–d
Dimenit	9.40	abc	6.50	b–e	7.95	ab	6.14	b-h	6.53	ab	6.34	a–d
Zerun	7.83	bc	6.50	b–e	7.17	ab	6.19	b-h	5.50	a–e	5.85	d-ı
Landrace mean	8.61		6.88		7.74		6.06		6.02		6.04	
Dağdaş 94	7.78	bc	6.97	a–d	7.38	ab	7.40	ab	4.97	cde	6.18	a–e
Müfitbey	10.13	abc	7.40	abc	8.77	a	4.11	j	5.63	a–e	4.87	j
Gün 91	10.13	abc	6.33	cde	8.23	ab	5.80	c-h	6.07	a–e	5.93	c–g
Aldane	8.27	abc	6.57	b–e	7.42	ab	4.91	hıj	4.97	cde	4.94	ıj
Bezostaja 1	10.53	ab	6.23	cde	8.38	ab	4.99	g–j	6.23	abc	5.61	d-j
Standard cultivar mean	9.37		6.70		8.04		5.44		5.57		5.51	
General mean	8.75		6.85		7.80		5.94		5.93		5.94	
C.V. (%)	14.16		6.88		12.02		8.61		9.02		8.82	

**There is no difference according to the significance level of 1% between the means in the same letter group. *C.V.* Coefficient of variation

the experiments carried out under late stress, plants were grown in natural precipitation conditions until the beginning of the booting stage (Feekes 10.0); when 50% of the cultivars reached the beginning of the booting stage, the trial areas were covered with a polyethylene shelter with open sides and transparent until the harvest on April 6, 2018, in the first year and April 25, 2019, in the second year. The covered area, which is positioned at a height of 1.5 m and at a distance of 1.5 m from the sides to the plots, is 3.8 m height and 11 m width. Drainage pits were dug in order to prevent rain water coming from the sides in the trials in which drought stress was created in both years. When the plants reached the harvest maturity, all plots were harvested with large scissors and the wheat sheaves were threshed with a threshing machine after drying in the field. In the study, the

Table 7 Canopy temperature differences at 25 days post-anthesis of bread wheat cultivars grown under irrigated and late drought stress conditions

Cultivar	Irrigated conditions						Late drought stress conditions					
	2017–2018		2018–2019		Average of two seasons		2017–2018		2018–2019		Average of two seasons	
TGB 003247	2.38	efg**	7.07	ıj**	4.73	ıj**	5.40	f**	7.47	a–d**	6.43	def**
TR 48371	2.28	fgh	8.83	fgh	5.56	e–h	4.25	ıj	8.20	ab	6.23	d-g
TGB 003246	1.75	ıj	9.80	b–f	5.78	c-f	7.07	bc	6.70	bcd	6.88	cd
TR 44433	2.50	def	7.47	hıj	4.98	g–j	6.80	cd	7.97	abc	7.38	abc
TGB 003232	2.07	h	7.47	hıj	4.77	ıj	5.00	g	6.93	a–d	5.97	e–h
TR 63581	2.13	h	8.87	fgh	5.50	e–h	7.15	b	7.97	abc	7.56	abc
TR 37373	1.55	j	8.40	f-ı	4.98	g–j	3.88	kl	7.90	abc	5.89	e–h
TGB 003249	2.85	bc	8.87	fgh	5.86	c-f	6.05	e	7.13	a–d	6.59	de
TR 63501	3.00	b	9.77	b–f	6.38	a–d	4.62	h	7.03	a–d	5.83	fgh
TR 63575	2.57	de	8.97	d-g	5.77	c-f	4.00	jk	6.70	bcd	5.35	hı
TGB 000534	2.10	h	10.33	a–e	6.22	a–e	8.85	a	7.13	a–d	7.99	a
TR 63497	1.82	ı	10.77	ab	6.29	a–d	8.62	a	6.97	a–d	7.79	a
TGB 003248	3.00	b	10.50	abc	6.75	a	8.53	a	6.70	bcd	7.62	ab
TGB 000543	2.23	gh	11.30	a	6.77	a	4.65	h	7.47	a–d	6.06	e–h
TGB 000526	4.02	a	8.90	e–h	6.46	abc	4.42	hı	6.57	cd	5.49	ghı
TGB 000521	2.93	b	9.87	b–f	6.40	abc	3.60	lm	6.33	d	4.97	ı
Çam buğdayı	2.25	gh	9.07	c–g	5.66	d-g	5.30	fg	6.53	cd	5.92	e–h
Çalı basıran	2.37	efg	9.60	b–g	5.98	b–f	5.30	fg	6.53	cd	5.92	e–h
Ak sunteri	2.70	cd	7.13	ıj	4.92	hıj	3.78	kl	7.47	a–d	5.63	ghı
Örmece	2.37	efg	11.40	a	6.88	a	6.67	d	7.97	abc	7.32	abc
Dimenit	3.05	b	8.60	fgh	5.83	c-f	5.25	fg	6.83	a–d	6.04	e–h
Zerun	2.83	bc	10.40	a–d	6.62	ab	6.58	d	4.20	e	5.39	hı
Landrace mean	2.49		9.25		5.87		5.72		7.03		6.38	
Dağdaş 94	2.22	gh	8.47	f-ı	5.34	f-ı	5.57	f	8.30	a	6.93	bcd
Müfitbey	3.98	a	8.77	fgh	6.38	a–d	5.45	f	7.33	a–d	6.39	def
Gün 91	2.50	def	9.33	b–g	5.92	b–f	3.30	m	6.53	cd	4.92	ı
Aldane	1.68	ıj	6.90	j	4.29	j	3.97	jk	7.20	a–d	5.58	ghı
Bezostaja 1	2.52	de	8.17	g–j	5.34	f-ı	7.26	b	6.47	cd	6.86	cd
Standard cultivar mean	2.58		8.33		5.46		5.11		7.17		6.14	
General mean	2.51 b		9.07 a**		5.79		5.60 b		7.06 a**		6.33	
C.V. (%)	3.84		6.38		7.17		2.52		8.41		6.82	

**There is no difference according to the significance level of 1% between the means in the same letter group. C.V.: coefficient of variation

leaf relative water content (Teulat et al. 1998), canopy temperature difference using a portable infrared thermometer (Araghi and Assad 1998) and leaf chlorophyll fluorescence parameters using a portable chlorophyll fluorometer (Guo et al. 2008) were determined. The leaf relative water content was determined four times at 5–6 day intervals, starting at the beginning of heading, and the obtained values were averaged. Canopy temperature difference and leaf chlorophyll fluorescence parameters were determined in three periods, anthesis, 15 days post-anthesis and 25 days post-anthesis.

The data obtained from the trial were subjected to the homogeneity test (Bartlett 1950), data of the two growing seasons were subjected to ANOVA separately and together, using the MSTAT-C Version 2.10 package program in accordance with the trail plan and in the comparison of the averages of the cultivars, and Duncan's multiple comparison test was used at $p \leq 0.05$ and $p \leq 0.01$ (Freed and Eisensmith 1986).

Table 8 Initial fluorescence at anthesis stage of bread wheat cultivars grown under irrigated and late drought stress conditions

Cultivar	Irrigated conditions			Late drought stress conditions		
	2017–2018	2018–2019	Average of two seasons	2017–2018	2018–2019	Average of two seasons
TGB 003247	176.5 ns	167.0 a–e*	171.8 a–d*	181.5 ns	150.0 ns	165.8 ns
TR 48371	175.0	180.7 abc	177.8 abc	157.0	150.7	153.8
TGB 003246	183.3	178.7 a–e	181.0 ab	175.0	160.7	167.8
TR 44433	170.0	159.2 cde	164.6 cd	175.3	157.3	166.3
TGB 003232	178.0	178.0 a–e	178.0 abc	180.7	159.5	170.1
TR 63581	181.2	185.3 a	183.3 a	175.0	157.3	166.2
TR 37373	170.3	155.8 e	163.1 d	171.3	156.3	163.8
TGB 003249	180.0	166.0 a–e	173.0 a–d	174.0	157.7	165.8
TR 63501	169.3	183.5 ab	176.4 a–d	173.7	163.8	168.8
TR 63575	181.3	163.0 a–e	172.2 a–d	186.7	159.7	173.2
TGB 000534	172.5	171.8 a–e	172.2 a–d	167.5	161.0	164.3
TR 63497	178.2	158.5 cde	168.3 bcd	178.0	163.5	170.8
TGB 003248	188.0	157.7 cde	172.8 a–d	181.8	158.7	170.3
TGB 000543	180.0	160.7 b–e	170.3 a–d	187.2	163.7	175.4
TGB 000526	181.8	167.5 a–e	174.7 a–d	181.3	161.8	171.6
TGB 000521	184.2	162.2 b–e	173.2 a–d	175.3	163.0	169.2
Çam buğdayı	179.3	165.0 a–e	172.2 a–d	169.8	164.5	167.2
Çalı basıran	178.7	174.7 a–e	176.7 a–d	179.2	163.5	171.3
Ak sunteri	172.0	160.2 cde	166.1 cd	174.5	161.5	168.0
Örmece	173.7	157.5 cde	165.6 cd	165.0	160.7	162.8
Dimenit	179.7	175.3 a–e	177.5 abc	175.7	156.5	166.1
Zerun	178.8	156.5 de	167.7 bcd	181.5	171.2	176.3
Landrace mean	177.8	167.5	172.7	175.8	160.1	168.0
Dağdaş 94	182.0	161.8 b–e	171.9 a–d	185.8	160.3	173.1
Müfitbey	186.3	179.5 a–d	182.9 a	184.3	165.5	174.9
Gün 91	176.8	169.3 a–e	173.1 a–d	174.0	166.3	170.2
Aldane	177.3	177.3 a–e	177.3 abc	182.0	160.7	171.3
Bezostaja 1	186.8	166.2 a–e	176.5 a–d	170.0	162.8	166.4
Standard cultivar mean	181.8	170.8	176.3	179.2	163.1	171.2
General mean	178.6	168.1	173.4	176.4	160.7	168.6
C.V. (%)	4.57	6.89	5.78	5.90	5.39	5.68

*There is no difference according to the significance level of 5% between the means in the same letter group

ns Not significant, *C.V.* Coefficient of variation

Rank analysis was performed on the parameters examined according to the combined years average in the conditions under which late drought stress was created. According to the rank analysis, the cultivars were ranked from largest to smallest according to each parameter value and the cultivar with the highest value was given rank value of 1 and the cultivar with the lowest value was given rank value of 27 (as much as the number of cultivars). After the ranking, the rank values exceeded the parameters for each cultivar were summed up and averaged; the rank average (rank mean), the standard deviation of the rank values of each cultivar from each parameter (rank standard deviation) and the rank sum (rank mean+rank standard deviation) were calculated. According to the rank sum, cultivars were divided into four groups as tolerant, moderately

Table 9 Initial fluorescence at 15 days post-anthesis of bread wheat cultivars grown under irrigated and late drought stress conditions

Cultivar	Irrigated conditions			Late drought stress conditions		
	2017–2018	2018–2019	Average of two seasons	2017–2018	2018–2019	Average of two seasons
TGB 003247	163.2 ns	167.3 ns	165.3 bc*	146.8 ns	155.2 ns	151.0 ns
TR 48371	158.7	182.7	170.7 ab	152.5	149.7	151.1
TGB 003246	156.0	169.0	162.5 bc	150.0	153.5	151.8
TR 44433	154.8	166.2	160.5 bc	149.7	149.2	149.4
TGB 003232	167.8	177.0	172.4 ab	164.8	145.0	154.9
TR 63581	160.7	175.3	168.0 abc	152.8	145.7	149.3
TR 37373	160.2	162.7	161.4 bc	145.2	150.3	147.8
TGB 003249	164.3	169.5	166.9 abc	151.8	154.2	153.0
TR 63501	161.0	168.7	164.8 bc	161.3	148.8	155.1
TR 63575	159.8	163.5	161.7 bc	152.0	166.7	159.3
TGB 000534	160.8	166.8	163.8 bc	145.8	150.8	148.3
TR 63497	165.0	173.7	169.3 ab	160.8	153.0	156.9
TGB 003248	152.5	173.3	162.9 bc	161.3	142.0	151.7
TGB 000543	150.5	158.2	154.3 c	154.2	158.5	156.3
TGB 000526	158.0	190.5	174.3 ab	153.2	150.2	151.7
TGB 000521	163.2	176.3	169.8 ab	149.8	146.7	148.3
Çam buğdayı	162.5	166.8	164.7 bc	153.8	144.0	148.9
Çalı basıran	154.8	187.8	171.3 ab	150.3	148.5	149.4
Ak sunteri	160.7	162.5	161.6 bc	157.5	149.0	153.3
Örmece	159.7	163.2	161.4 bc	157.8	148.2	153.0
Dimenit	175.0	175.8	175.4 ab	151.0	145.7	148.3
Zerun	158.2	164.5	161.3 bc	154.7	167.3	161.0
Landrace mean	160.3	171.0	165.7	153.5	151.0	152.3
Dağdaş 94	164.3	181.8	173.1 ab	161.5	153.8	157.7
Müfitbey	160.3	179.7	170.0 ab	167.5	154.3	160.9
Gün 91	161.8	183.5	172.7 ab	160.5	149.5	155.0
Aldane	172.2	189.2	180.7 a	149.3	150.2	149.8
Bezostaja 1	163.0	172.2	167.6 abc	155.0	149.5	153.3
Standard cultivar mean	164.3	181.3	172.8	158.8	151.5	155.2
General mean	161.1	172.9	167.0	154.5	151.1	152.8
C.V. (%)	5.16	7.20	6.34	6.36	6.24	6.30

*There is no difference according to the significance level of 5% between the means in the same letter group. C.V.: coefficient of variation

ns Not significant

tolerant, moderately sensitive and sensitive by creating a frequency table in drought tolerance (Kang 1988).

Results

Leaf relative water content (%)

The difference between bread wheat cultivars in leaf relative water content was not significant in the first year although it was significant ($p \leq 0.01$) in the second year in the irrigated

Table 10 Initial fluorescence at 25 days post-anthesis of bread wheat cultivars grown under irrigated and late drought stress conditions

Cultivar	Irrigated conditions						Late drought stress conditions					
	2017–2018		2018–2019		Average of two seasons		2017–2018		2018–2019		Average of two seasons	
TGB 003247	154.5	de**	173.3	abc*	163.9	bcd**	155.0	ns	150.3	ns	152.7	ns
TR 48371	159.8	b–e	165.2	bcd	162.5	bcd	157.2		135.8		146.5	
TGB 003246	156.5	cde	161.7	bcd	159.1	bcd	163.8		146.3		155.1	
TR 44433	163.8	bcd	162.7	bcd	163.2	bcd	153.8		158.7		156.3	
TGB 003232	176.0	ab	165.7	bcd	170.8	b	169.0		151.8		160.4	
TR 63581	159.8	b–e	166.7	bcd	163.2	bcd	169.0		147.0		158.0	
TR 37373	156.8	cde	159.2	bcd	158.0	bcd	150.7		136.3		143.5	
TGB 003249	150.8	de	160.2	bcd	155.5	bcd	165.0		151.0		158.0	
TR 63501	157.5	cde	174.0	ab	165.8	bcd	161.0		143.8		152.4	
TR 63575	160.3	b–e	167.3	a–d	163.8	bcd	154.8		141.8		148.3	
TGB 000534	166.3	a–d	162.5	bcd	164.4	bcd	155.2		147.8		151.5	
TR 63497	155.5	cde	165.7	bcd	160.6	bcd	154.8		151.7		153.3	
TGB 003248	159.0	cde	156.5	bcd	157.8	bcd	165.7		163.7		164.7	
TGB 000543	153.5	de	173.3	abc	163.4	bcd	165.5		156.5		161.0	
TGB 000526	153.3	de	157.8	bcd	155.6	bcd	176.3		150.7		163.5	
TGB 000521	145.8	e	168.5	a–d	157.1	bcd	150.3		145.5		147.9	
Çam buğdayı	153.8	de	155.3	bcd	154.6	d	171.5		149.8		160.7	
Çalı basıran	150.8	de	165.0	bcd	157.9	bcd	156.7		156.2		156.4	
Ak sunteri	156.3	cde	153.8	cd	155.1	cd	173.5		142.5		158.0	
Örmece	161.0	b–e	161.3	bcd	161.2	bcd	156.3		153.0		154.7	
Dimenit	161.0	b–e	152.0	d	156.5	bcd	162.2		144.2		153.2	
Zerun	167.5	a–d	173.2	abc	170.3	bc	165.7		149.8		157.8	
Landrace mean	158.2		163.7		161.0		161.5		148.8		155.2	
Dağdaş 94	158.3	cde	170.5	a–d	164.4	bcd	171.2		149.3		160.3	
Müfitbey	155.5	cde	174.3	ab	164.9	bcd	162.7		146.0		154.3	
Gün 91	181.8	a	186.3	a	184.1	a	183.3		151.8		167.6	
Aldane	168.3	a–d	171.5	a–d	169.9	bcd	165.7		149.5		157.6	
Bezostaja 1	172.5	abc	168.7	a–d	170.6	b	172.5		150.2		161.3	
Standard cultivar mean	167.3		174.3		170.8		171.1		149.4		160.3	
General mean	**159.8**		**165.6**		**162.7**		**163.3 a***		**148.9 b**		**156.1**	
C.V. (%)	4.16		5.95		5.17		8.85		6.13		7.74	

*, **There is no difference according to the significance level of 5% and 1%, respectively, between the means in the same letter group

ns Not significant, *C.V.* Coefficient of variation

conditions, 1% in the first year, 5% in the second year in the late drought stress conditions and 1% in both conditions according to the results of the combined analysis of the years found significant (Table 4). In irrigated conditions, mean leaf relative water content was higher in landraces (86.1%) in the first year and higher in registered varieties (81.0%) in the second year; according to the results of the combined analysis of the years, the leaf relative water content changed between 80.6 and 84.7% and the average of the registered cultivars was found to be higher than the landraces (Table 4). In the conditions where late drought stress was created, lower leaf relative water content values were obtained in landraces compared to registered cultivars in the both years. In the average of years, the relative water content varied between 73.0 and 81.5% (Table 4).

Table 11 Maximum fluorescence at anthesis stage of bread wheat cultivars grown under irrigated and late drought stress conditions

Cultivar	Irrigated conditions						Late drought stress conditions					
	2017–2018		2018–2019		Average of two seasons		2017–2018		2018–2019		Average of two seasons	
TGB 003247	730.3	f*	720.0	bcd*	725.2	cd**	930.8	a–d**	726.3	de*	828.6	b–e**
TR 48371	805.3	b–f	780.7	a–d	793.0	bcd	797.5	d	786.0	a–e	791.8	e
TGB 003246	811.3	b–f	799.0	abc	805.2	bcd	897.5	a–d	733.5	cde	815.5	de
TR 44433	744.0	ef	701.5	cd	722.8	cd	884.3	a–d	709.0	e	796.7	e
TGB 003232	760.0	def	750.5	bcd	755.3	bcd	999.8	ab	864.0	ab	931.9	ab
TR 63581	832.2	a–f	848.5	ab	840.3	abc	901.2	a–d	778.5	b–e	839.8	a–e
TR 37373	789.0	c-f	651.5	d	720.3	d	854.2	a–d	810.8	a–e	832.5	b–e
TGB 003249	858.3	a–e	727.0	bcd	792.7	bcd	891.5	a–d	733.2	cde	812.3	de
TR 63501	829.8	a–f	701.5	cd	765.7	bcd	896.7	a–d	819.5	a–e	858.1	a–e
TR 63575	852.0	a–f	709.2	cd	780.6	bcd	990.3	abc	829.8	a–d	910.0	a–d
TGB 000534	861.8	a–e	697.2	cd	779.5	bcd	864.5	a–d	778.5	b–e	821.5	cde
TR 63497	803.0	b–f	713.3	cd	758.2	bcd	942.5	a–d	812.3	a–e	877.4	a–e
TGB 003248	825.0	a–f	725.3	bcd	775.2	bcd	931.2	a–d	783.8	a–e	857.5	a–e
TGB 000543	821.0	a–f	739.7	bcd	780.3	bcd	902.7	a–d	850.5	ab	876.6	a–e
TGB 000526	866.8	a–e	724.8	bcd	795.8	bcd	949.7	a–d	804.2	a–e	876.9	a–e
TGB 000521	883.2	a–d	707.0	cd	795.1	bcd	871.8	a–d	806.7	a–e	839.3	a–e
Çam buğdayı	848.3	a–f	684.3	cd	766.3	bcd	839.3	bcd	818.0	a–e	828.7	b–e
Çalı basıran	796.5	c-f	711.5	cd	754.0	bcd	926.0	a–d	842.0	abc	884.0	a–e
Ak sunteri	796.8	c-f	732.7	bcd	764.8	bcd	931.0	a–d	831.3	a–d	881.2	a–e
Örmece	842.8	a–f	711.7	cd	777.3	bcd	885.3	a–d	770.3	b–e	827.8	b–e
Dimenit	824.7	a–f	714.0	cd	769.3	bcd	914.3	a–d	805.0	a–e	859.7	a–e
Zerun	823.8	a–f	715.3	cd	769.6	bcd	948.7	a–d	839.0	abc	893.8	a–e
Landrace mean	818.5		725.7		772.1		906.9		796.9		851.9	
Dağdaş 94	924.7	ab	747.5	bcd	836.1	a–d	1006.7	a	854.7	ab	930.2	ab
Müfitbey	890.5	abc	720.7	bcd	805.6	bcd	987.8	abc	869.2	ab	928.5	abc
Gün 91	879.8	a–d	724.2	bcd	802.0	bcd	831.5	cd	806.0	a–e	818.8	de
Aldane	937.7	a	896.8	a	917.3	a	985.3	abc	895.8	a	940.6	a
Bezostaja 1	908.3	abc	810.7	abc	859.5	ab	906.8	a–d	865.0	ab	885.9	a–e
Standard cultivar mean	908.2		780.0		844.1		943.6		858.1		900.9	
General mean	835.1		735.8		785.5		913.6 a*		808.3 b		861.0	
C.V. (%)	7.86		9.11		8.19		6.75		6.93		6.84	

*, **There is no difference according to the significance level of 5% and 1%, respectively, between the means in the same letter group

C.V Coefficient of variation

In the study, the difference between years in relative water content of the leaves was found to be significant at the level of 1% under irrigated conditions, but insignificant under drought stress conditions (Table 4). The average leaf relative water content of the cultivars was determined as 86.1% in the first year, 79.6% in the second year in the irrigated conditions, 76.3% in the first year and 77.9% in the second year in the late drought stress conditions; leaf water content decreased in late drought stress conditions compared to irrigated conditions in both experiment years.

Table 12 Maximum fluorescence at 15 days post-anthesis of bread wheat cultivars grown under irrigated and late drought stress conditions

Cultivar	Irrigated conditions						Late drought stress conditions					
	2017–2018		2018–2019		Average of two seasons		2017–2018		2018–2019		Average of two seasons	
TGB 003247	685.7	bcd**	783.3	a–e**	734.5	bcd**	685.5	def*	724.3	ns	704.9	a–d**
TR 48371	728.5	bcd	790.7	a–e	759.6	bcd	748.0	a–f	755.0		751.5	a–d
TGB 003246	722.2	bcd	752.5	a–e	737.3	bcd	714.5	c-f	708.0		711.3	a–d
TR 44433	670.3	d	673.7	cde	672.0	d	707.2	c-f	670.8		689.0	cd
TGB 003232	725.7	bcd	793.5	a–e	759.6	bcd	856.8	a	745.7		801.3	ab
TR 63581	743.3	a–d	743.7	a–e	743.5	bcd	748.2	a–f	673.8		711.0	a–d
TR 37373	676.7	cd	747.2	a–e	711.9	cd	711.3	c-f	680.2		695.8	bcd
TGB 003249	653.2	d	812.5	a–e	732.8	bcd	753.7	a–f	714.3		734.0	a–d
TR 63501	698.8	bcd	714.0	b–e	706.4	cd	735.3	a–f	706.7		721.0	a–d
TR 63575	685.5	bcd	717.8	b–e	701.7	cd	689.8	c-f	760.0		724.9	a–d
TGB 000534	757.3	a–d	652.8	e	705.1	cd	713.0	c-f	764.0		738.5	a–d
TR 63497	750.3	a–d	800.7	a–e	775.5	bcd	758.3	a–f	793.0		775.7	abc
TGB 003248	661.2	d	747.8	a–e	704.5	cd	666.2	ef	680.8		673.5	cd
TGB 000543	686.5	bcd	699.7	b–e	693.1	cd	787.8	a–e	744.2		766.0	a–d
TGB 000526	734.7	bcd	780.8	a–e	757.8	bcd	721.0	b–f	719.2		720.1	a–d
TGB 000521	724.0	bcd	781.8	a–e	752.9	bcd	654.0	f	671.7		662.8	d
Çam buğdayı	743.2	a–d	729.2	b–e	736.2	bcd	743.3	a–f	693.3		718.3	a–d
Çalı basıran	741.5	a–d	846.5	a–e	794.0	bcd	698.0	c-f	694.8		696.4	bcd
Ak sunteri	697.2	bcd	726.8	b–e	712.0	cd	783.3	a–e	720.8		752.1	a–d
Örmece	771.7	a–d	659.2	de	715.4	cd	697.2	c-f	730.8		714.0	a–d
Dimenit	675.3	cd	749.0	a–e	712.2	cd	703.8	c-f	720.8		712.3	a–d
Zerun	714.7	bcd	760.2	a–e	737.4	bcd	806.3	a–d	818.7		812.5	a
Landrace mean	711.3		748.3		729.8		731.0		722.3		726.7	
Dağdaş 94	774.3	a–d	862.3	a–d	818.3	abc	844.0	ab	787.8		815.9	a
Müfitbey	743.8	a–d	885.7	ab	814.8	abc	816.8	abc	796.2		806.5	ab
Gün 91	830.2	abc	791.5	a–e	810.8	abc	804.3	a–d	766.0		785.2	abc
Aldane	886.5	a	934.7	a	910.6	a	746.8	a–f	813.8		780.3	abc
Bezostaja 1	834.3	ab	866.0	abc	850.2	ab	791.2	a–e	743.3		767.3	a–d
Standard cultivar mean	813.8		868.0		840.9		800.6		781.4		791.0	
General mean	730.2		770.5		750.4		743.9		733.3		738.6	
C.V. (%)	8.11		10.04		9.18		8.55		7.97		8.27	

*, **There is no difference according to the significance level of 5% and 1%, respectively, between the means in the same letter group

ns Not significant, *C.V.* Coefficient of variation

Canopy temperature difference (°C)

The difference between the cultivars in the three periods was measured; it was found to be statistically significant ($p \leq 0.01$) in the both years and in the average of years in irrigated and late drought stress conditions (Tables 5, 6 and 7). According to the results of the combined analysis of the years, the canopy temperature difference: at anthesis stage between 5.51 (TGB 003249) and 7.08 °C (TR 63497) under irrigated conditions, between 4.44 (TR 37373) and 6.11 °C (Gün 91) under drought stress conditions, at 15 days post-anthesis between 6.96 (TGB 003248) and 8.77 °C (Müfitbey) under irrigated conditions, between 4.87 (Müfitbey) and 6.99 (TR 63497) under drought stress conditions, at 25 days post-anthesis between 4.29 (Aldane) and 6.88 °C

Table 13 Maximum fluorescence at 25 days post-anthesis of bread wheat cultivars grown under irrigated and late drought stress conditions

Cultivar	Irrigated conditions			Late drought stress conditions		
	2017–2018	2018–2019	Average of two seasons	2017–2018	2018–2019	Average of two seasons
TGB 003247	689.5 f**	784.8 ab**	737.2 bcd**	679.3 ns	689.5 ns	684.4 ns
TR 48371	794.8 a–e	679.0 b	736.9 bcd	697.3	642.0	669.7
TGB 003246	752.0 b–f	771.3 ab	761.7 bcd	762.2	683.8	723.0
TR 44433	779.5 a–f	739.0 ab	759.3 bcd	679.0	716.3	697.7
TGB 003232	794.8 a–e	760.7 ab	777.7 abc	740.8	704.7	722.8
TR 63581	762.0 b–f	648.0 b	705.0 cd	750.5	625.8	688.2
TR 37373	786.5 a–f	638.3 b	712.4 cd	710.7	681.3	696.0
TGB 003249	695.8 ef	736.8 ab	716.3 cd	730.5	682.8	706.7
TR 63501	780.8 a–f	766.8 ab	773.8 abc	690.5	656.5	673.5
TR 63575	774.0 a–f	652.3 b	713.2 cd	689.8	686.3	688.1
TGB 000534	803.3 a–d	620.8 b	712.0 cd	664.3	679.7	672.0
TR 63497	804.3 a–d	770.8 ab	787.5 abc	680.0	712.3	696.2
TGB 003248	708.0 def	732.2 ab	720.1 cd	697.0	724.3	710.7
TGB 000543	738.5 c-f	737.7 ab	738.1 bcd	800.3	713.7	757.0
TGB 000526	739.5 c-f	737.5 ab	738.5 bcd	780.8	697.0	738.9
TGB 000521	759.0 b–f	706.0 ab	732.5 bcd	649.5	673.5	661.5
Çam buğdayı	715.8 def	616.8 b	666.3 d	733.8	631.7	682.8
Çalı basıran	762.0 b–f	759.7 ab	760.8 bcd	699.8	740.3	720.1
Ak sunteri	737.3 c-f	665.2 b	701.2 cd	776.7	601.5	689.1
Örmece	744.5 b–f	643.8 b	694.2 cd	724.8	679.3	702.1
Dimenit	743.5 c-f	671.7 b	707.6 cd	731.3	631.5	681.4
Zerun	828.0 abc	733.8 ab	780.9 abc	721.8	648.3	685.1
Landrace mean	758.8	707.9	733.4	717.8	677.4	697.6
Dağdaş 94	765.5 a–f	683.7 b	724.6 cd	789.0	726.3	757.7
Müfitbey	758.5 b–f	778.2 ab	768.3 a–d	743.7	731.8	737.8
Gün 91	752.3 b–f	796.7 ab	774.5 abc	777.7	683.2	730.4
Aldane	846.3 ab	884.5 a	865.4 a	547.8	749.5	648.7
Bezostaja 1	862.5 a	798.3 ab	830.4 ab	784.3	727.0	755.7
Standard cultivar mean	797.0	788.3	792.7	728.5	723.6	726.1
General mean	765.9	722.8	744.4	719.8	685.9	702.9
C.V. (%)	5.11	9.74	7.65	10.99	9.25	10.20

**There is no difference according to the significance level of 1% between the means in the same letter group.

ns Not significant, *C.V.* Coefficient of variation

(Örmece) under irrigated conditions and between 4.92 (Gün 91) and 7.99 °C (TGB 000534) under drought stress conditions, changed (Table 5).

Difference between years in canopy temperature difference was found to be significant at the level of 1% at anthesis and 25 days post-anthesis, but non-significant at 15 days post-anthesis in both irrigated and late drought stress conditions. Average canopy temperature difference, according to the results of the combined analysis of the years: at anthesis stage 6.32 °C under irrigated conditions, 5.19 °C under drought stress conditions, at 15 days post-anthesis 7.80 °C under irrigated conditions, 5.94 °C under drought stress conditions, at 25 post-anthesis 5.79 °C under irrigated conditions and 6.33 °C under drought stress conditions, was found (Tables 5, 6 and 7).

Table 14 Variable fluorescence at anthesis stage of bread wheat cultivars grown under irrigated and late drought stress conditions

Cultivar	Irrigated conditions						Late drought stress conditions					
	2017–2018		2018–2019		Average of two seasons		2017–2018		2018–2019		Average of two seasons	
TGB 003247	553.8	e*	553.0	bcd*	553.4	c**	749.3	abc**	576.3	bc**	662.8	c-f**
TR 48371	630.3	b–e	600.0	bcd	615.2	bc	640.5	c	635.3	abc	637.9	f
TGB 003246	628.0	b–e	620.3	a–d	624.2	bc	722.5	abc	572.8	bc	647.7	f
TR 44433	574.0	de	542.3	bcd	558.2	c	709.0	abc	551.7	c	630.3	f
TGB 003232	582.0	de	572.5	bcd	577.3	bc	819.2	a	704.5	ab	761.8	ab
TR 63581	651.0	a–e	663.2	ab	657.1	abc	726.2	abc	621.2	abc	673.7	a–f
TR 37373	618.7	cde	495.7	d	557.2	c	701.2	abc	654.5	abc	677.8	a–f
TGB 003249	678.3	a–d	561.0	bcd	619.7	bc	717.5	abc	575.5	bc	646.5	f
TR 63501	659.5	a–e	518.0	d	588.8	bc	723.0	abc	655.7	abc	689.3	a–f
TR 63575	670.7	a–d	546.2	bcd	608.4	bc	770.8	abc	670.2	abc	720.5	a–f
TGB 000534	689.3	a–d	525.3	cd	607.3	bc	697.0	abc	617.5	abc	657.3	def
TR 63497	624.8	cde	554.8	bcd	589.8	bc	764.5	abc	648.8	abc	706.7	a–f
TGB 003248	637.0	b–e	567.7	bcd	602.3	bc	749.3	abc	625.2	abc	687.3	a–f
TGB 000543	641.0	b–e	579.0	bcd	610.0	bc	715.5	abc	686.8	abc	701.2	a–f
TGB 000526	685.0	a–d	557.3	bcd	621.2	bc	768.3	abc	642.3	abc	705.3	a–f
TGB 000521	699.0	abc	544.8	bcd	621.9	bc	696.5	abc	643.7	abc	670.1	b–f
Çam buğdayı	669.0	a–e	519.3	d	594.2	bc	669.5	bc	653.5	abc	661.5	c-f
Çalı basıran	617.8	cde	536.8	cd	577.3	bc	811.7	ab	678.5	abc	745.1	a–e
Ak sunteri	624.8	cde	572.5	bcd	598.7	bc	756.5	abc	669.8	abc	713.2	a–f
Örmece	669.2	a–e	554.2	bcd	611.7	bc	720.3	abc	609.7	abc	665.0	c-f
Dimenit	645.0	a–e	538.7	cd	591.8	bc	738.7	abc	648.5	abc	693.6	a–f
Zerun	645.0	a–e	558.8	bcd	601.9	bc	767.2	abc	667.8	abc	717.5	a–f
Landrace mean	640.6		558.2		599.4		733.4		636.8		685.1	
Dağdaş 94	742.7	ab	585.7	bcd	664.2	abc	819.8	a	694.3	ab	757.1	abc
Müfitbey	704.3	abc	541.2	bcd	622.8	bc	803.5	ab	703.7	ab	753.6	a–d
Gün 91	702.3	abc	554.8	bcd	628.6	bc	657.5	c	639.7	abc	648.6	ef
Aldane	759.5	a	719.5	a	739.5	a	803.3	ab	735.2	a	769.3	a
Bezostaja 1	721.5	abc	644.5	abc	683.0	ab	736.8	abc	702.2	ab	719.5	a–f
Standard cultivar mean	726.1		609.1		667.6		764.2		695.0		729.6	
General mean	656.4		567.7		612.1		739.1 a*		647.6 b		693.4	
C.V. (%)	8.88		10.91		9.83		7.40		7.95		7.66	

*, **There is no difference according to the significance level of 5% and 1%, respectively, between the means in the same letter group

C.V. Coefficient of variation

Leaf chlorophyll fluorescence parameters

The average initial fluorescence (F_0) of bread wheat cultivars, under irrigated conditions, respectively, at anthesis stage, at 15 and 25 days post-anthesis, was between 163.1 and 183.3, 154.3 and 180.7, 154.6 and 184.1, under late drought stress conditions between 153.8 and 176.3, 147.8 and 161.0, 143.5 and 167.6 changed (Tables 8, 9 and 10). Average F_0 values in all three stages measured were lower in landraces than registered cultivars in both irrigated and late drought stress conditions in both years. Also, when looking at the F_0 values of the cultivars under drought stress conditions: at anthesis stage TGB 000543 and TR 63575 in the first year, Zerun landraces in the second year (Table 8), at 15 days post-anthesis stage Zerun, TR 63575, TGB 000543

Table 15 Variable fluorescence at 15 days post-anthesis of bread wheat cultivars grown under irrigated and late drought stress conditions

Cultivar	Irrigated conditions						Late drought stress conditions					
	2017–2018		2018–2019		Average of two seasons		2017–2018		2018–2019		Average of two seasons	
TGB 003247	522.5	c**	616.0	a–e**	569.3	bcd**	538.7	ns	569.2	a–e*	553.9	abc**
TR 48371	569.8	bc	608.0	a–e	588.9	bcd	595.5		605.3	a–e	600.4	abc
TGB 003246	566.2	bc	583.5	a–e	574.8	bcd	564.5		554.5	b–e	559.5	abc
TR 44433	515.5	c	507.5	cde	511.5	d	557.5		521.7	e	539.6	c
TGB 003232	557.8	bc	616.5	a–e	587.2	bcd	697.0		600.7	a–e	648.8	ab
TR 63581	582.7	abc	568.3	a–e	575.5	bcd	595.3		528.2	de	561.8	abc
TR 37373	516.5	c	584.5	a–e	550.5	cd	566.3		529.8	de	548.1	bc
TGB 003249	488.8	c	643.0	a–e	565.9	cd	601.8		560.2	a–e	581.0	abc
TR 63501	537.7	bc	545.3	b–e	541.5	cd	579.0		557.8	a–e	568.4	abc
TR 63575	525.7	c	554.3	b–e	540.0	cd	537.8		593.3	a–e	565.5	abc
TGB 000534	596.5	abc	486.0	e	541.3	cd	567.2		613.2	a–e	590.2	abc
TR 63497	585.3	abc	627.0	a–e	606.2	bcd	597.5		640.0	abc	618.8	abc
TGB 003248	508.7	c	574.5	a–e	541.6	cd	504.8		538.8	cde	521.8	c
TGB 000543	536.0	bc	541.5	b–e	538.8	cd	633.7		585.7	a–e	609.7	abc
TGB 000526	576.7	abc	590.3	a–e	583.5	bcd	567.8		569.0	a–e	568.4	abc
TGB 000521	560.8	bc	605.5	a–e	583.2	bcd	554.2		525.0	e	539.6	c
Çam buğdayı	580.7	abc	562.3	a–e	571.5	bcd	589.5		549.3	b–e	569.4	abc
Çalı basıran	586.7	abc	658.7	a–e	622.7	bcd	597.7		546.3	b–e	572.0	abc
Ak sunteri	586.5	abc	564.3	a–e	575.4	bcd	625.8		571.8	a–e	598.8	abc
Örmece	612.0	abc	496.0	de	554.0	cd	539.3		582.7	a–e	561.0	abc
Dimenit	500.3	c	573.2	a–e	536.8	cd	552.8		575.2	a–e	564.0	abc
Zerun	556.5	bc	595.7	a–e	576.1	bcd	651.7		651.3	ab	651.5	ab
Landrace mean	553.2		577.4		565.3		582.5		571.3		576.9	
Dağdaş 94	610.0	abc	680.5	a–d	645.3	abc	682.5		634.0	a–d	658.3	a
Müfitbey	583.5	abc	706.0	ab	644.8	abc	666.0		641.8	abc	653.9	ab
Gün 91	668.3	ab	608.0	a–e	638.2	abc	643.8		616.5	a–e	630.2	abc
Aldane	714.3	a	745.5	a	729.9	a	597.5		663.7	a	630.6	abc
Bezostaja 1	671.3	ab	693.8	abc	682.6	ab	636.2		593.8	a–e	615.0	abc
Standard cultivar mean	649.5		686.8		668.2		645.2		630.0		637.6	
General mean	571.0		597.6		584.3		594.1		582.2		588.2	
C.V. (%)	9.52		11.90		10.83		10.83		9.21		10.07	

*, **There is no difference according to the significance level of 5% and 1%, respectively, between the means in the same letter group

ns Not significant, C.V. Coefficient of variation

and TGB 003247 landraces in the second year (Table 9), at 25 days post-anthesis stage TGB 003248, TR 44433, TGB 000543, Çalı basıran and Örmece landraces in the second year (Table 10) attracted attention by having higher F_0 values than registered cultivars in the same years.

The average maximum fluorescence (F_m) of bread wheat cultivars, respectively, at anthesis stage, at 15 and 25 days post-anthesis, under irrigated conditions between 720.3 and 917.3, 672.0 and 910.6, 666.3 and 865.4, under late drought stress conditions between 791.8 and 940.6, 662.8 and 815.9, 648.7 and 757.7 changed (Tables 11, 12 and 13).

The average variable fluorescence yields (F_v) of bread wheat cultivars, respectively, at anthesis stage, at 15 and 25 days post-anthesis, under irrigated conditions between 553.4 and 739.5, 511.5 and 729.9, 511.8 and 695.5, under late drought stress conditions between 630.3 and 769.3, 521.8 and 658.3, 491.1 and 597.4 changed (Tables 14, 15 and 16). The average photosystem II (PS II) maximum energy efficiency (F_v/F_m) of bread wheat cultivars, respectively, at anthesis

Table 16 Variable fluorescence at 25 days post-anthesis of bread wheat cultivars grown under irrigated and late drought stress conditions

Cultivar	Irrigated conditions			Late drought stress conditions		
	2017–2018	2018–2019	Average of two seasons	2017–2018	2018–2019	Average of two seasons
TGB 003247	535.0 d**	611.5 ab**	573.3 bcd**	524.3 ns	539.2 ns	531.8 ns
TR 48371	635.0 a–d	513.8 b	574.4 bcd	540.2	506.2	523.2
TGB 003246	595.5 a–d	609.7 ab	602.6 a–d	598.3	537.5	567.9
TR 44433	615.8 a–d	576.3 ab	596.0 a–d	525.2	557.7	541.4
TGB 003232	618.8 a–d	595.0 ab	606.9 a–d	571.8	552.8	562.3
TR 63581	602.3 a–d	481.3 b	541.8 cd	581.5	478.8	530.2
TR 37373	629.8 a–d	479.2 b	554.5 cd	560.0	545.0	552.5
TGB 003249	545.0 cd	576.7 ab	560.8 bcd	565.5	531.8	548.7
TR 63501	623.3 a–d	592.8 ab	608.0 a–d	529.5	512.7	521.1
TR 63575	613.8 a–d	485.0 b	549.4 cd	535.0	544.5	539.8
TGB 000534	637.0 a–d	458.3 b	547.7 cd	509.2	531.8	520.5
TR 63497	648.8 a–d	605.2 ab	627.0 abc	525.2	560.7	542.9
TGB 003248	549.0 cd	575.7 ab	562.3 bcd	531.3	560.7	546.0
TGB 000543	585.0 a–d	564.3 ab	574.7 bcd	634.8	557.2	596.0
TGB 000526	586.3 a–d	579.7 ab	583.0 bcd	604.5	546.3	575.4
TGB 000521	613.3 a–d	537.5 ab	575.4 bcd	549.2	528.0	538.6
Çam buğdayı	562.0 bcd	461.5 b	511.8 d	562.3	481.8	522.1
Çalı basıran	611.3 a–d	594.7 ab	603.0 a–d	593.2	584.2	588.7
Ak sunteri	573.5 bcd	511.3 b	542.4 cd	603.2	459.0	531.1
Örmece	658.5 abc	482.5 b	570.5 bcd	568.5	526.3	547.4
Dimenit	582.5 a–d	519.7 b	551.1 cd	569.2	487.3	528.3
Zerun	660.5 abc	560.7 ab	610.6 a–d	556.2	498.5	527.3
Landrace mean	603.7	544.2	574.0	560.8	528.5	544.7
Dağdaş 94	607.3 a–d	513.2 b	560.2 bcd	617.8	577.0	597.4
Müfitbey	603.0 a–d	603.8 ab	603.4 a–d	580.8	585.8	583.3
Gün 91	570.5 bcd	610.3 ab	590.4 bcd	592.7	531.3	562.0
Aldane	678.0 ab	713.0 a	695.5 a	382.2	600.0	491.1
Bezostaja 1	690.0 a	629.7 ab	659.8 ab	611.8	576.8	594.3
Standard cultivar mean	629.8	614.0	621.9	557.1	574.2	565.6
General mean	608.5	557.1	582.8	560.1	537.0	548.6
C.V. (%)	7.22	12.16	9.80	12.00	11.04	11.55

**There is no difference according to the significance level of 1% between the means in the same letter group

ns Not significant, *C.V.* Coefficient of variation

stage, at 15 and 25 days post-anthesis, under irrigated conditions between 0.761 and 0.806, 0.751 and 0.818, 0.761 and 0.814, under late drought stress conditions between 0.790 and 0.842, 0.773 and 0.819, 0.741 and 0.827 changed (Tables 17, 18 and 19).

Classification of cultivars in drought tolerance according to the rank method

The rank sum values of the cultivars varied between 9.90 and 27.22 (Table 20), and bread wheat cultivars were grouped according to the scale in Table 20. Accordingly, TGB 003232 from landraces, Dağdaş 94 and Müfitbey from registered cultivars were among the drought tolerant group and drew attention. These cultivars can be defined as having high drought tolerance potential with low rank mean values. In addition, the standard deviations of the mean ranks

Table 17 Photosystem II (PS II) maximum energy efficiency at anthesis stage of bread wheat cultivars grown under irrigated and late drought stress conditions

Cultivar	Irrigated conditions						Late drought stress conditions					
	2017–2018		2018–2019		Average of two seasons		2017–2018		2018–2019		Average of two seasons	
TGB 003247	0.758	f*	0.768	ns	0.763	d*	0.805	b**	0.793	b–e**	0.799	b**
TR 48371	0.781	a–f	0.768		0.775	bcd	0.802	b	0.808	abc	0.805	b
TGB 003246	0.773	b–f	0.777		0.775	bcd	0.805	b	0.781	de	0.793	b
TR 44433	0.767	def	0.772		0.769	cd	0.802	b	0.777	e	0.790	b
TGB 003232	0.760	ef	0.761		0.761	d	0.819	b	0.814	ab	0.817	b
TR 63581	0.782	a–f	0.780		0.781	bcd	0.806	b	0.797	a–e	0.802	b
TR 37373	0.784	a–f	0.755		0.770	bcd	0.819	b	0.807	abc	0.813	b
TGB 003249	0.790	a–e	0.770		0.780	bcd	0.805	b	0.784	cde	0.794	b
TR 63501	0.795	a–d	0.737		0.766	d	0.806	b	0.800	a–e	0.803	b
TR 63575	0.786	a–f	0.771		0.779	bcd	0.778	b	0.808	abc	0.793	b
TGB 000534	0.800	abc	0.752		0.776	bcd	0.806	b	0.793	b–e	0.799	b
TR 63497	0.778	a–f	0.777		0.778	bcd	0.811	b	0.798	a–e	0.805	b
TGB 003248	0.770	c-f	0.783		0.777	bcd	0.805	b	0.797	a–e	0.801	b
TGB 000543	0.780	a–f	0.783		0.782	bcd	0.793	b	0.807	abc	0.800	b
TGB 000526	0.790	a–e	0.768		0.779	bcd	0.809	b	0.799	a–e	0.804	b
TGB 000521	0.792	a–e	0.771		0.781	bcd	0.798	b	0.797	a–e	0.798	b
Çam buğdayı	0.789	a–f	0.759		0.774	bcd	0.798	b	0.799	a–e	0.798	b
Çalı basıran	0.775	b–f	0.754		0.764	d	0.880	a	0.804	a–d	0.842	a
Ak sunteri	0.784	a–f	0.781		0.783	bcd	0.812	b	0.805	a–d	0.809	b
Örmece	0.794	a–d	0.779		0.786	a–d	0.814	b	0.791	b–e	0.803	b
Dimenit	0.782	a–f	0.754		0.768	cd	0.807	b	0.805	a–d	0.806	b
Zerun	0.783	a–f	0.780		0.782	bcd	0.808	b	0.796	a–e	0.802	b
Landrace mean	0.782		0.768		0.775		0.809		0.798		0.804	
Dağdaş 94	0.803	ab	0.784		0.794	abc	0.815	b	0.813	ab	0.814	b
Müfitbey	0.790	a–e	0.751		0.771	bcd	0.813	b	0.808	abc	0.811	b
Gün 91	0.798	a–d	0.766		0.782	bcd	0.791	b	0.794	b–e	0.793	b
Aldane	0.810	a	0.802		0.806	a	0.815	b	0.821	a	0.818	b
Bezostaja 1	0.795	a–d	0.795		0.795	ab	0.812	b	0.811	ab	0.812	b
Standard cultivar mean	0.799		0.780		0.790		0.809		0.809		0.809	
General mean	0.785 a*		0.770 b		0.778		0.809		0.800		0.805	
C.V. (%)	2.05		2.59		2.33		2.27		1.45		1.91	

*, **There is no difference according to the significance level of 5% and 1%, respectively, between the means in the same letter group

ns Not significant, *C.V.* Coefficient of variation

of Dağdaş 94, Müfitbey and TGB 003232 cultivars were determined as the lowest (5.50, 6.81 and 7.75, respectively), and these cultivars were found to be the most stable in the selection criteria which is considered. Bezostaja 1 (9.44), TR 63497 (10.38), TGB 000543 (10.44), Çalı basıran (10.63) and Zerun (11.81) followed these cultivars in decreasing order in stability. Bezostaja 1, TR 63497, TGB 000543, TGB 000526 and Çalı basıran cultivars with rank sum values varying between 14.77 and 18.40 were found to be moderately drought-tolerant (Table 20).

Discussion

It has been reported that stomatal conductivity, photosynthesis, transpiration rate and leaf relative moisture content decrease in plants exposed to drought stress (Yavas 2010; Anjum et al. 2011; Jamali et al. 2020; Wasaya et al. 2021). The average leaf relative water content was lower in the second year compared to the first year under irrigated conditions, and in the first year compared to the second year under late drought stress conditions (Table 4). In irrigated conditions, the increase in the current moisture content in the soil (Fig. 1) due to the high amount of precipitation falling after

Table 18 Photosystem II (PS II) maximum energy efficiency at 15 days post-anthesis of bread wheat cultivars grown under irrigated and late drought stress conditions

Cultivar	Irrigated conditions						Late drought stress conditions					
	2017–2018		2018–2019		Average of two seasons		2017–2018		2018–2019		Average of two seasons	
TGB 003247	0.760	ns	0.786	ns	0.773	b–e*	0.785	ns	0.795	ns	0.790	ns
TR 48371	0.780		0.768		0.774	b–e	0.796		0.802		0.799	
TGB 003246	0.784		0.774		0.779	b–e	0.788		0.783		0.786	
TR 44433	0.769		0.753		0.761	de	0.787		0.778		0.782	
TGB 003232	0.769		0.776		0.773	b–e	0.814		0.804		0.809	
TR 63581	0.783		0.764		0.773	b–e	0.795		0.784		0.789	
TR 37373	0.762		0.783		0.772	b–e	0.796		0.776		0.786	
TGB 003249	0.748		0.791		0.770	b–e	0.798		0.783		0.791	
TR 63501	0.770		0.760		0.765	de	0.787		0.788		0.787	
TR 63575	0.766		0.771		0.769	b–e	0.779		0.781		0.780	
TGB 000534	0.788		0.744		0.766	cde	0.796		0.802		0.799	
TR 63497	0.777		0.782		0.780	b–e	0.787		0.807		0.797	
TGB 003248	0.768		0.766		0.767	b–e	0.755		0.791		0.773	
TGB 000543	0.781		0.772		0.776	b–e	0.804		0.787		0.796	
TGB 000526	0.784		0.754		0.769	b–e	0.788		0.791		0.789	
TGB 000521	0.775		0.775		0.775	b–e	0.848		0.782		0.815	
Çam buğdayı	0.781		0.769		0.775	b–e	0.791		0.792		0.792	
Çalı basıran	0.789		0.777		0.783	b–e	0.852		0.786		0.819	
Ak sunteri	0.859		0.777		0.818	a	0.799		0.793		0.796	
Örmece	0.792		0.751		0.772	b–e	0.772		0.796		0.784	
Dimenit	0.739		0.763		0.751	e	0.784		0.798		0.791	
Zerun	0.779		0.783		0.781	b–e	0.808		0.796		0.802	
Landrace mean	0.777		0.770		0.774		0.796		0.791		0.794	
Dağdaş 94	0.787		0.788		0.788	a–d	0.808		0.805		0.807	
Müfitbey	0.782		0.798		0.790	a–d	0.816		0.805		0.811	
Gün 91	0.806		0.763		0.784	b–e	0.800		0.805		0.802	
Aldane	0.806		0.797		0.801	abc	0.800		0.815		0.808	
Bezostaja 1	0.804		0.801		0.803	ab	0.804		0.797		0.801	
Standard cultivar mean	0.797		0.789		0.793		0.806		0.805		0.806	
General mean	0.781 a*		0.774 b		0.778		0.798		0.793		0.796	
C.V. (%)	3.78		2.60		3.25		5.09		1.84		3.83	

*There is no difference according to the significance level of 5% between the means in the same letter group

ns Not significant, *C.V.* Coefficient of variation

the first year's booting period (Table 1) may be the reason for the increase in the relative water content of the leaves in the first year. In drought stress conditions, it is thought that the relative water content of the leaves decreases due to the lower soil moisture content (Fig. 1) in the first year. According to the results of the combined analysis of the years, a higher leaf relative water content value was obtained from the landrace TGB 003232 compared to the registered cultivars (except for Müfitbey) under late drought stress conditions and was determined that it was drought-tolerant (Table 4). Indeed, it has been reported that high leaf relative water content in droughty conditions is an indicator of drought tolerance (Silva et al. 2007).

When Tables 5, 6 and 7 are examined, canopy temperature differences varied according to varieties, years, wet conditions and drought stress conditions. It has been reported that the canopy temperature difference varies depending on many factors; it may not be accurate to compare the results of different studies, even different years or locations of the same study (Ozturk and Aydin 2014). The average canopy temperature difference was higher in the first year compared to measured other years in the measurement 15 days post-anthesis, under irrigated and drought stressed conditions.

Table 19 Photosystem II (PS II) maximum energy efficiency at 25 days post-anthesis of bread wheat cultivars grown under irrigated and late drought stress conditions

Cultivar	Irrigated conditions						Late drought stress conditions					
	2017–2018		2018–2019		Average of two seasons		2017–2018		2018–2019		Average of two seasons	
TGB 003247	0.776	b**	0.779	ab*	0.778	bcd*	0.770	ns	0.780	ns	0.775	ns
TR 48371	0.799	b	0.756	ab	0.778	bcd	0.773		0.787		0.780	
TGB 003246	0.790	b	0.789	ab	0.790	a–d	0.785		0.786		0.785	
TR 44433	0.790	b	0.779	ab	0.785	a–d	0.772		0.779		0.776	
TGB 003232	0.779	b	0.780	ab	0.780	bcd	0.770		0.784		0.777	
TR 63581	0.790	b	0.742	b	0.766	cd	0.775		0.762		0.769	
TR 37373	0.801	b	0.748	ab	0.774	bcd	0.788		0.800		0.794	
TGB 003249	0.782	b	0.778	ab	0.780	bcd	0.773		0.779		0.776	
TR 63501	0.798	b	0.773	ab	0.786	a–d	0.766		0.781		0.773	
TR 63575	0.792	b	0.742	b	0.767	cd	0.776		0.793		0.784	
TGB 000534	0.793	b	0.733	b	0.763	cd	0.766		0.782		0.774	
TR 63497	0.807	b	0.785	ab	0.796	abc	0.767		0.787		0.777	
TGB 003248	0.775	b	0.786	ab	0.781	bcd	0.762		0.774		0.768	
TGB 000543	0.792	b	0.761	ab	0.776	bcd	0.794		0.779		0.786	
TGB 000526	0.793	b	0.783	ab	0.788	a–d	0.774		0.784		0.779	
TGB 000521	0.808	b	0.760	ab	0.784	a–d	0.857		0.780		0.818	
Çam buğdayı	0.785	b	0.747	ab	0.766	cd	0.764		0.762		0.763	
Çalı basıran	0.802	b	0.780	ab	0.791	a–d	0.866		0.787		0.827	
Ak sunteri	0.778	b	0.767	ab	0.772	bcd	0.776		0.763		0.769	
Örmece	0.880	a	0.748	ab	0.814	a	0.784		0.773		0.779	
Dimenit	0.784	b	0.773	ab	0.778	bcd	0.778		0.772		0.775	
Zerun	0.798	b	0.759	ab	0.779	bcd	0.770		0.767		0.769	
Landrace mean	0.795		0.766		0.781		0.782		0.779		0.781	
Dağdaş 94	0.792	b	0.751	ab	0.772	bcd	0.783		0.792		0.787	
Müfitbey	0.795	b	0.776	ab	0.786	a–d	0.780		0.800		0.790	
Gün 91	0.756	b	0.766	ab	0.761	d	0.761		0.777		0.769	
Aldane	0.801	b	0.806	a	0.804	ab	0.682		0.800		0.741	
Bezostaja 1	0.799	b	0.789	ab	0.794	a–d	0.779		0.793		0.786	
Standard cultivar mean	0.789		0.778		0.784		0.757		0.792		0.775	
General mean	0.794 a**		0.768 b		0.781		0.777		0.782		0.780	
C.V. (%)	2.99		2.98		2.99		6.07		2.33		4.59	

*, **There is no difference according to the significance level of 5% and 1%, respectively, between the means in the same letter group

ns Not significant, *C.V.* Coefficient of variation

In addition, a similar result was obtained in the second year measurement made 25 days post-anthesis. It is thought that this situation is for the high transpiration rates due to the high ambient temperature during the measurement (Kumari et al. 2013; Ozturk and Aydin 2014). Considering the two-year averages under irrigated and drought stress conditions, it is thought that the canopy temperature differences measured at anthesis and 15 days post-anthesis decrease under late drought stress conditions as a result of reduction in suitable soil moisture and low transpiration rates (Tables 5 and 6).

According to the results of the combined analysis of the years, the average F_0 values of the cultivars decreased gradually at 15 and 25 days post-anthesis stages in the irrigated conditions; there was decrease at 15 days post-anthesis stage in the drought stress conditions compared to the anthesis stage (Tables 8, 9 and 10). These reductions are thought to be related to the possible high photosynthetic light intensity during measurement. It has been reported that excessive light energy on the leaf causes deterioration in the heat conversion mechanism and reduces the F0 value (Guo et al 2008). Average F_m values in all three stages measured were lower in landraces than registered cultivars

Table 20 Classification of wheat landraces for their drought response according to rank mean, standard deviation of average rank and rank sum

Cultivar	Rank mean	Standard deviation	Rank sum	Tolerant (9.90–14.23)	Moderately tolerant (14.24–18.57)	Sensitive (18.58–22.91)	Moderately sensitive (22.92–27.25)
TGB 003247	5.23	17.13	22.35	Dağdaş 94	Bezostaja 1	Ak sunteri	Aldane
TR 48371	8.63	15.63	24.26	TGB 003232	TR 63497	Zerun	TR 63501
TGB 003246	6.36	16.19	22.55	Müfitbey	TGB 000543	Gün 91	TR 63581
TR 44433	6.24	19.81	26.05		TGB 000526	Dimenit	TGB 003248
TGB 003232	5.18	7.75	12.93		Çalı basıran	TGB 003249	TR 63575
TR 63581	6.30	17.06	23.36			TGB 003247	TR 48371
TR 37373	7.94	17.88	25.82			Örmece	Çam buğdayı
TGB 003249	5.84	16.38	22.22			TGB 003246	TGB 000534
TR 63501	4.95	18.06	23.01				TR 37373
TR 63575	8.36	15.25	23.61				TR 44433
TGB 000534	7.49	17.56	25.05				TGB 000521
TR 63497	5.07	10.38	15.45				
TGB 003248	8.10	15.44	23.54				
TGB 000543	7.02	10.44	17.46				
TGB 000526	5.74	12.06	17.81				
TGB 000521	9.91	17.31	27.22				
Çam buğdayı	7.00	17.31	24.31				
Çalı basıran	7.78	10.63	18.40				
Ak sunteri	5.42	14.00	19.42				
Örmece	6.11	16.38	22.48				
Dimenit	5.50	16.56	22.06				
Zerun	9.13	11.81	20.94				
Dağdaş 94	4.40	5.50	9.90				
Müfitbey	6.92	6.81	13.73				
Gün 91	9.03	12.63	21.66				
Aldane	10.30	12.63	22.93				
Bezostaja 1	5.33	9.44	14.77				

in both irrigated and late drought stress conditions in both years. Considering the late drought stress conditions, it is seen that the mean F_m values gradually decrease for the three periods (Tables 11, 12 and 13). In some studies, it has been reported that drought stress reduces the F_m value (Bogale et al. 2011; Ozturk and Aydin 2014). According to the results of the combined analysis of the years, the average F_v values were found to be lower in landraces than registered cultivars in both irrigated and late drought stress conditions, in all three stages measured. Considering the late drought stress conditions, it is seen that the average F_v values for the three periods gradually decrease (Tables 14, 15 and 16). In studies on the subject, it has been reported that drought stress reduces the F_v value (Zlatev 2009; Bogale et al. 2011; Ozturk and Aydin 2014). According to the results of the combined analysis of the years, it is seen that the average F_v/F_m values of the cultivars for the three periods decreased gradually under the late drought stress conditions (Tables 17, 18 and 19). Ozturk and Aydin (2017) also reported that the F_v/F_m value decreased under late drought stress conditions.

The cultivars with the lowest standard deviations of the mean ranks were found to be the most stable in the selection criteria considered. As a matter of fact, it has been reported by Ozturk and Aydin (2017) that genotypes with low rank standard deviation were the most stable in the selection criteria examined.

Conclusions

Significant variations were obtained among the landraces in the physiological traits examined; the responses of the cultivars to different years and applications changed. According to the results obtained, TGB 003232, TR 63581 and TGB 000534 landraces showed higher values than the average of registered cultivars in leaf relative water content under late drought stress conditions. According to the results of the rank analysis, as reported in studies, Dağdaş

94 and Müfitbey cultivars are used as standard drought-tolerant cultivars and TGB 003232 landrace became prominent in drought tolerance at late developmental stages. In the F_v/F_m value used to determine the drought tolerance of the genotypes, Çalı basıran bread wheat landrace becomes prominent in all three stages observed. It is important to use landraces in breeding studies as a gene source or directly as a variety in different environments.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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