Available online at www.scholarsresearchlibrary.com

Scholars Research Library

Annals of Biological Research, 2012, 3 (3):1322-1333
(http://scholarsresearchlibrary.com/archive.html)

ISSN 0976-1233
CODEN (USA): ABRNBW

Using different indices for selection of resistant wheat cultivars to post anthesis water deficit in the west of Iran

Abdoli M. and Saeidi M*

Department of Agronomy and Plant Breeding, Campus of Agriculture and Natural Resources, Razi University, Iran

---

ABSTRACT

Water deficit is a major cause in reduction of crop production. Evaluate of phonological and morphological traits and resistance indices to post anthesis water deficit can help to identify strategies for selection of resistant cultivars and increased crop yield production. To this end, an experiment was laid out in a split–plot arranged in a randomized complete blocks design with three replications during 2011-2012 season in research farm of Razi university in Iran. The results showed that post anthesis water deficit significantly decreased grain yield, biomass, grain weight and grain number per spick, days to maturity and grain filling periods among different traits in cultivars. Under water deficiency and control treatments, cultivars in terms of all evaluated traits had significant differences. Correlation analysis between grain yield (under water deficiency and control treatments) with different drought resistance indices showed that STI (Stress Tolerance Index), GMP (Geometric Mean production) and MP (Mean Production) indices were appropriate indicators for identification of cultivars with high grain yield in both water deficiency and control treatments. Based on these indicators, Sivand and DN-11 had the highest grain yield in both moisture treatments. And based on SSI and TOL (Tolerance) indices, Chamran was the most resistant cultivar under post anthesis water deficit stress. According to the results, cultivation of DN-11 and Sivand cultivars in such regions is associated with lower risk. Chamran cultivar also is appropriate for physiological studies to discover the mechanisms of drought tolerance to transfer them to susceptible cultivars.

Keywords: Wheat, Water deficiency, Resistance indices, Phenology, Morphology.

INTRODUCTION

Plant Breeders and physiologists that studied drought tolerance in plants for years are argued that crop yield affected by environmental conditions, genetic structure and their interactions. Among the various forms of environmental stresses, drought stress is the most important factor that limiting growth and economic yield production of crops such as wheat [8, 11] via reducing leaf growth [10, 17, 18], chlorophyll concentration [7], soluble protein concentration [37], stomatal conductants [26], accelerating senescence of leaves [55] and reducing the rate of photosynthesis [55]. Of course amount of damage to the plant production depends on the severity and duration of stress application, plant resistance and plant growth stage [50].

Due to the geographical situation, Iran's climate is Mediterranean and with respect to average participation (240 mm), is considered as dry and semi dry regions of the world [23]. Flowering and grain filling of wheat are the most sensitive stages to environmental stresses such as water deficit [55]. Water stress in such areas often occurs during these periods. Under such conditions, provide of carbohydrates that's needed for grain filling to formation of economical yield is very important. In general, several sources provide carbohydrate during grain filling. Such sources are included, current photosynthesis and carbohydrates that stored in the stems before and after flowering [19, 9]. Generally, much of the grains reserves are made after flowering. So their construction at this stage is strongly affected by the drought [2].

Due to the importance of damages that caused by post anthesis water deficit, evaluation of plant responses to this situation is highly regarded [32]. In this condition grain yield and its stability considered as two important indices for selecting and producing of wheat cultivars [51]. Under different climatic conditions, an extensive genetic variation have been reported for traits such as; grain and biological yield, harvest index and 1000 grain's weight between different wheat genotypes [2, 3, 12, 53]. In most cases, cultivars that in both water stress and non-water stress conditions have greater grain yield or at least a little grain yield difference are selected [41]. In most experiments, cultivars based on different various indices such as stress sensitivity and stress tolerance are evaluated [15, 34]. Usually based on these indices, genotypes are fitted in the four groups: the first group will produce a high yield in both environments, the second and third groups in normal and stress conditions respectively are produced high grain yield. The grain yield of fourth group in both conditions is low [15].

Despite of numerous investigations in connection with the detection of resistant and susceptible cultivars under environmental stresses in other conditions and with respect to the importance of environmental effects on plant productivity, the aim of this study was to evaluate the physiological characteristics and sensitivity and resistance indices under post-anthesis water deficit in the main improved wheat cultivars that are cultivated in the west of Iran.

MATERIALS AND METHODS

The present study was conducted during 2010-2011 in the field research of Razi university in Kermanshah state in the west of Iran (47º, 9′/E; 34º, 21′/ N), 1319 meter elevated from sea level. The research was in a field where the previous crop was a corn. The soil was a clay loam (36.1% clay, 30.7% silt) and the experiment was laid out in a split–plot arranged in a randomized complete blocks design with three replications. Evaluated treatments were included that moisture regimes and different improved bread wheat cultivars (*Triticum aestivum* L.). Two levels of moisture regimes (includes: Irrigation in all stages of plant growth normally and post-anthesis water deficiency with withholding of irrigation) as the main-plot and different improved cultivars (includes: Bahar, Parsi, Pishtaz, Pishgam, Chamran, Zarin, Sivand, Marvdasht, DN-11) as sub-plot were considered. These cultivars were chosen because of their contrasting grain yield productivity and the highest area under cultivation in the west of Iran. Also, occurred almost every year of post-anthesis water deficit in cultivated area in these regions, was the most reason for selection of these treatments. Date of anthesis was determined from middle rows in each plot when 50% of the spikes had extruded anthers [9]. Each plot included 54 rows 20 cm apart, 4 meter long, 4 and 3 meter distances were taken between test plots and replicates, respectively. Seeds were sown at a density of 400 seeds m^{-2} on 12^{th} October. Based on soil analysis, nitrogenous fertilizer as urea ($CO(NH_2)_2$) was applied prior to planting, as topdressing at tillering stage and at flowering stage, 80kg N/ha^{-1} in each stage.

Taking notes during the growing season to estimate the number of days to 50% flowering, days to physiological maturity and grain filling period was performed. Biomass and grain yield for each cultivar were measured by harvesting 2 m^2 of the central part of each plot at crop maturity. Harvest index was measured by dividing grain yield to biomass production. In order to measuring grain yield components such as: no of grains per spick, fertile and infertile spikelet number, grain weight, spike length, peduncle and stem length, 10 plants randomly selected and measurements were performed.

In order to estimates the sensitivity and tolerance indices in post anthesis water deficit in different improved wheat cultivars, the relationships that proposed by Fischer and Maurer [16], Rosielle and Hamblin [38] and Fernandez [15] were used. These indices are includes:

Stress Susceptibility Index (SSI)	$SSI= [1-(Y_s/Y_p)]/SI$
Stress Index (SI)	$SI= 1- (\bar{Y}s)(\bar{Y}p)$
Tolerance Index (TOL)	$TOL= Y_p-Y_s$
Mean Production (MP)	$MP= (Y_s+Y_p)/2$
Geometric Mean Production (GMP)	$GMP= \sqrt{(Ys)(Yp)}$
Stress Tolerance Index (STI)	$STI= (Ys)(Yp)/(\bar{Y}p)^2$
Harmonic Mean (HARM)	$HARM= 2\times(Y_s)(Y_p)/(Y_s+Y_p)$

In the above formulas, abbreviations are as follows:
Y_p and Y_s: Grain yield of each cultivars under Control and water deficit respectively. $\bar{Y}p$ and $\bar{Y}s$: Means of grain yield of each cultivars under control and water deficit respectively.

Statistical analyses were performed using MSTATC and SAS soft wares. Mean comparisons were also performed using LSD at 5% level. Humidity and moderate temperatures during the crop season is presented in Table 1.

RESULT AND DISCUSSION

Effects of water regimes on yield and its components and agronomic traits

The results obtained from mean comparison analysis of grain yield and its components are shown in Table 2. showed that post anthesis water deficiency stress caused 34 and 27 percent reduction in grain yield and grain weight in average respectively, but had no significant effect on no of grain $spick^{-1}$ and no of spick m^{-2}. The averages of grain yield and grain weight of different cultivars in controlled condition were 701 gm^{-2} and 42.4 g respectively, while under water deficiency stress these values significantly reduced to 463 gm^{-2} and 31.2 g. The findings from [40], when they imposed water deficit at different stages of grain growth separately, showed that significant reduction in grain yield production in these conditions may be result of reducing the production of photo-assimilates (source limitation) for grain filling, reducing the sink power to absorb of photo-assimilates and reducing the grain filling duration. They also reported that probably, the early processes of grain growth (cell division and formation of sink size) are less affected by water deficiency. Therefore, grain weight and grain yield reduction under post anthesis water deficiency may be more reflects the lack of photo-assimilates supply for grain filling. These findings also are in agreement with Shah and Paulsen [43], Yang and Zang [55], Ehdaie [9] and [2].

Table 1. Minimum, Maximum and Mean of temperature and relative humidity also precipitation in the Kermanshah region in the west of Iran during 2010-2011

Month	Min temp (C°)	Max temp (C°)	Mean temp (C°)	Precipitation (mm)	Min RH (%)	Max RH (%)	Mean RH (%)
Oct.	10.6	30.3	20.4	1	13.2	46.4	29.8
Nov.	4.5	21.9	13.2	31	22.8	66.8	44.8
Dec.	-1.5	16.8	7.7	24	26.5	62.4	44.5
Jan.	-2.2	9.6	3.7	50	47.1	91.0	69.1
Feb.	-2.7	8.0	2.7	65	52.1	94.2	73.2
Mar.	0.6	15.4	8	21	28.1	82.0	55
Apr.	4.5	20.1	12.3	47	24.6	78.8	51.7
May.	9.5	23.6	16.5	128	33.6	87.4	60.5
Jun.	12.8	33.8	23.3	0	11.3	51.1	31.2
Jul.	17.1	38.5	27.8	0	6.6	32.1	19.4

Under control treatment, Chamran (561 gm^{-2}) cultivar had the lowest and Sivand and DN-11 cultivars (783 and 750 gm^{-2} respectively) had the highest grain yield (Table 1). Under Post anthesis water deficiency, the lowest and highest significant reductions in grain yield were seen in Chamran (20%) and Zarin (38%) cultivars respectively. Minimum grain yield production under post anthesis water deficiency was related to the Marvdasht cultivar (410 gm^{-2}). So, planting of Marvdasht cultivar in such area where there is potential for occurrence of post anthesis water deficit may be associated with high risk.

In post anthesis water deficiency, the highest reduction in grain weight was seen in Parsi and Marvdasht cultivars and lowest reduction was seen in DN-11 and Chamran cultivars (Table 2). There was a significant positive correlation between no of spick m^{-2} and grain yield and also between no of spick m^{-2} and biomass (Table 4). Probably increasing the number of spikes m^{-2} was due to more property of tillering in cultivars. This property increases the number of the grains m^{-2} and thus increases the grain yield.

Between control and post anthesis water deficiency conditions, in terms of number of spicks m^{-2} and grain number $spick^{-1}$ were no significant differences (Table 3). This result is probably because the potential of these components are formed before spick initiation, so post anthesis water deficiency stress has no significant influence on them [4, 24, 43, 49].

Table 2. Mean comparisons of grain yield and its components and some morphological and phonological traits in different improved wheat cultivars under post anthesis water deficiency in the west of Iran

Number	Cultivars	Grain Yield (g/m^2)		Decrease ** (%)	Biomass (g/m^2)		Harvest Index (%)		1000 Grain Weight (g)		Decrease (%)
		Water	Stress		Water	Stress	Water	Stress	Water	Stress	
1	Bahar	724	474	-34.4	1203	933	60.2	50.9	42.1	31.9	-24.4
2	Parsi	692	437	-36.8	1230	880	56.3	49.7	45.4	29.8	-34.3
3	Pishtase	705	496	-29.5	1196	933	58.9	53.2	46.6	32.3	-30.8
4	Pishgam	717	445	-37.9	1120	790	64.1	56.4	43.2	32.4	-24.9
5	Chamran	561	447	-20.4	1016	800	55.3	55.9	43.2	36.2	-16.0
6	Zarin	724	447	-38.2	1253	976	57.8	45.8	39.2	27.7	-29.4
7	Sivand	782	496	-36.6	1236	980	63.3	50.7	45.5	32.7	-28.3
8	Marvdasht	656	410	-37.4	1063	870	61.7	47.2	36.7	24.5	-33.4
9	DN-11	750	515	-31.3	1286	936	58.3	55.0	39.9	33.7	-15.6
Mean		701.6	463.5	-33.9	1178.5	900.0	59.5	51.6	42.4	31.2	-26.4
LSD(%5)		154.4			164.23		8.41		6.07		
CV(%)		13.03			10.99		3.89		5.4		

Continued table 2.

Number	Cultivars	Number of Grain Per Spike		Number of Spike Per m^2		Spike Length (cm)		Peduncle Length (cm)		Plant Height (cm)	
		Water	Stress	Water	Stress	Water	Stress	Water	Stress	Water	Stress
1	Bahar	45.2	51.2	516	425	9.4	9.8	33.7	34.0	84.3	85.7
2	Parsi	37.2	40.5	502	423	8.5	8.2	31.2	29.7	82.7	80.6
3	Pishtase	38.3	38.1	503	427	8.8	8.4	35.0	34.8	86.3	82.3
4	Pishgam	52.0	52.6	444	351	8.4	8.8	33.7	33.0	77.0	77.3
5	Chamran	32.6	35.4	437	436	8.0	8.2	29.3	27.5	84.6	79.9
6	Zarin	57.5	56.3	467	400	10.8	10.8	38.2	38.3	100	97.0
7	Sivand	38.8	39.6	523	450	8.4	8.3	32.5	31.3	83.5	80.2
8	Marvdasht	56.5	55.2	404	427	8.9	8.8	30.5	29.7	84.5	82.9
9	DN-11	44.9	45.0	512	408	9.3	9.3	31.5	31.7	87.8	86.7
Mean		44.8	46.0	479.1	416.7	8.9	9.0	32.8	32.2	85.7	83.6
LSD(%5)		8.79		105.5		0.48		1.33		1.8	
CV(%)		9.51		9.24		4.13		4.3		2.48	

Continued table 2.

Number	Cultivars	Days to Flowering		Days to Physiological Maturity		Grain Filling Period		Fertile Spikelet		Infertile Spikelet	
		Water	Stress	Water	Stress	Water	Stress	Water	Stress	Water	Stress
1	Bahar	170	171	207	198	37.7	27.7	17.0	18.1	2.3	1.8
2	Parsi	167	169	204	195	37.3	26.3	15.3	15.5	3.2	2.3
3	Pishtase	169	170	209	200	39.7	30.0	15.0	14.6	3.0	2.4
4	Pishgam	168	169	207	198	39.3	29.7	16.8	17.7	1.8	1.3
5	Chamran	167	167	203	194	36.0	26.3	14.5	15.5	4.0	3.7
6	Zarin	170	170	206	197	35.7	27.0	18.0	18.2	1.8	1.4
7	Sivand	168	169	206	197	38.0	28.3	15.4	15.2	2.8	2.4
8	Marvdasht	170	169	208	199	37.7	29.7	17.8	18.6	1.0	1.0
9	DN-11	167	167	203	194	36.0	26.7	16.4	16.5	2.3	2.1
Mean		168.7	169.2	206.1	197.1	37.5	28.0	16.2	16.6	2.5	2.1
LSD(%5)		1.56		0		1.56		1.51		0.94	
CV(%)		0.32		0.2		2.13		6.28		18.35	

**In each column, compared to the 5% level of LSD method is used.*
**Percentage decrease down control when water deficiency was applied at post anthesis.

Table 3. The effect of water deficiency and cultivar treatments on grain yield and its components and some morphological and phonological traits in improved wheat cultivars under post anthesis water deficiency in west of Iran

	Y*	B	HI	1000 GW	NGS	NSP	SL	PL	PH	DTF	DPM	GFP	FS	NFS
								Irrigation						
Water	701a	1178a	44.6a	42.4a	44.7a	479 a	8.9a	32.8a	85.7a	1686a	206a	37.4a	16.2a	2.4a
Stress	463b	900b	38.6a	31.2b	45.9a	416 a	8.9a	32.2a	83.6b	1698a	197b	27.9b	16.6a	2.0a
Decrees (%)	-33.9	-23.6	-13.5	-26.4	2.7	-13.0	0.3	-1.9	-2.4	0.3	-4.4	-25.4	2.6	-6.3
								Cultivars						
Bahar	599ab	1068ab	41.7b	37.0bc	48.2bc	470ab	9.5b	33.8b	85.0bc	170a	203b	32.6c	17.5ab	2.0de
Parsi	564abc	1055ab	39.5cd	37.5abc	38.8de	462abc	8.3de	30.4de	81.7 e	168d	199d	31.8d	15.4cd	2.7b
Pishtase	601ab	1065ab	41.9b	39.4a	38.2de	465ab	8.6cd	34.9 b	84.3cd	169b	204 a	34.8a	14.8d	2.6b
Pishgam	581abc	955bc	45.1a	37.8abc	52.3ab	397d	8.6cd	33.3bc	77.1f	168c	203b	34.5a	17.2ab	1.5e
Chamran	504c	908c	41.8b	39.7a	34.0e	437bcd	8.1e	28.4f	82.2de	167e	198e	31.1d	14.9d	3.8a
Zarin	585abc	1115a	38.7d	33.4d	56.8a	433bcd	10.8a	38.2a	98.8a	170a	201c	31.3d	18.0a	1.5e
Sivand	639a	1108a	42.4b	39.1ab	39.1d	486a	8.3de	31.9cd	81.8e	168c	201c	33.1bc	15.2cd	2.6bc
Marvdasht	533bc	966bc	40.8bc	30.6 e	55.8a	416cd	8.8c	30.0e	83.7cde	169b	203b	33.6b	18.2a	1.0f
DN-11	632a	1111a	42.3b	36.7c	44.9c	460abc	9.3b	31.5de	87.3b	167e	198e	31.3d	16.4bc	2.1cd

**Y: Grain Yield (g/m^2), B: Biomass (g/m^2), HI: Harvest Index (%), 1000GW: 1000 Grain Weight (g), NGS: Number of Grain Per Spike, NSP: Number of Spike Per m^2, SL: Spike Length (cm), PL: Peduncle Length (cm), PH: Plant Height (cm), DTF: Days to Flowering, DPM: Days to Physiological Maturity, GFP: Grain Filling Period, FS: Fertile Spikelet, NFS: Non Fertile Spikelet.*

Mean values followed by the same letter (a-e) are not significantly different according to LSD (P<0.05).

It can be seen from the data in Table 2. that significant differences were found among cultivars in terms of grains spike^{-1} and spike m^{-2}. In term of the number grains spik^{-1}, Zarin and Marvdasht cultivars had the highest (56.8 and 55.8 grain spick^{-1}, respectively) and Chamran cultivar (34 grain spick^{-1}) had the lowest values. In term of the spicks m^{-2} under control condition, Sivand and DN-11 cultivars had the highest (523 and 512 spicks m^{-2}) and Marvdasht had the lowest values (351 spicks m^{-2}). Under post anthesis water deficiency stress Sivand (450 spicks m^{-2}) and Pishgam cultivars had the highest (450 spicks m^{-2}) and lowest (351 spicks m^{-2}) values. In control and stress conditions, a negative correlation was found between grain weight and grain number spick^{-1} (Table 4). The findings of the current study are consistent with those of Moral et al., [30] who found that also negative correlation between these two traits. They concluded that this negative correlation is related to compensation effect of yield components on each other. In this situation, by increasing the number grain spick-1, plants cannot fill all of them and then this is caused shrinking of grains and finally caused weight loss of the grains. This phenomenon is more serious under water deficiency stress.

The harvest index can be expressed as ability of plants to allocate photosynthetic material to produce economic yield. In terms of this trait under control and post anthesis water deficiency stress, there was significant variation between cultivars. Post anthesis water stress significantly decreased harvest index in most cultivars (Table 2). In control condition, Pishgam and Chamran cultivars had the highest (64.1%) and the lowest (55.3%) harvest index and in post anthesis water deficiency stress Pishgam and Zarin cultivars had the highest (56.4%) and the lowest (45.8%) harvest index. Significant reduction in harvest index under post anthesis water deficiency stress showed that dehydration stress as shown in Table 2. is largely due to more significant reduction in grain yield production than biomass production [42]. In 2002, Richards et al., demonstrated that for this reason that harvest index is indicators of the genetic potential of plant to produce economic yield, high harvest index under control treatment can be accompanied with high grain yield under water stress. The findings of the current study are consistent with those of Reynolds et al., [35] who found wheat cultivars that have high biological yield and harvest index, most likely have high grain yield under stress and control conditions. A point to note in this connection was that Chamran cultivar under post anthesis water deficiency with lowest reduction in harvest index had also the lowest reduction in grain yield production and Sivand, Zarin and Marvdasht with highest reduction in harvest index had also the higher reduction in grain yield production. In post anthesis water deficiency, a positive correlation was found between grain weight and harvest index. It means that increasing of grain weight is accompanied with increasing harvest index [25].

In order to determinate the effect of post anthesis water deficiency on plants height, average height of all cultivars in both conditions were compared. The results showed that, post anthesis water deficiency reduced the average height from 7.85 to 6.83 cm (2.5% reduction) (Table 3). Mitra, [29] interpreted the same result as a mechanism to evade plants from water stress. In terms of plant height in controlled conditions Zarin cultivar with about 100 cm had the largest and Pishgam with about 77 cm had the lowest plant height. Reduction in plant height under post anthesis water deficiency is probably because of reduction in peduncle internode length with respect to its growth completion after pollination. In this situation also Zarin and Pishgam cultivar had the highest (97 cm) and lowest (77 cm) plant height respectively.

Post anthesis water deficiency stress had no significant effect on peduncle and penultimate height (Despite of insignificant reduction in most cases in the length of the peduncle) (Table 3) but there were significant differences between cultivars for these traits. Under both conditions, Zarin cultivar had maximum spick length (10.8 cm) and peduncle length (38.3 cm) and Chamran the minimum spick length (8.1 cm) and maximum peduncle length (28.4 cm) (Table 3). Post anthesis water deficit had no significant effect on the number of fertile and infertile spicklets but in terms of these properties a wide range of variation in different cultivars was observed. In terms of fertile spicklets in each spick, Marvdasht and Zarin cultivars had the highest (18.1 and 18.2 respectively) and Chamran and Pishtaz cultivars had the lowest (14.8 and 14.9 respectively) values. Zarin and Pishgam cultivar had the lowest (1.5 and 1.6 respectively) and Chamran cultivar the highest (3.88) values of infertile spicklets in each spick (Table 3). The competition between spike and stem for absorb of leaf produced photo-assimilates initiates from beginning of terminal spicklet production, at anthesis and when the upper stem internodes are in growth and development stage in their structure reaches its maximum. Wheat cultivars that have the greater spick should have more power to maintain floret, increase number of grain, grain yield and harvest index [35]. In contrast to the number of grains per spike, there was a significant negative correlation between grain weight and fertile spicklet and a significant positive correlation between grain weight and infertile spicklet. Of course, high grain weight and number of fertile spicklets are very effective in increasing grain yield [33].

Table 4. Correlation coefficients among grain yield and its components with some morphological and phonological traits in improved wheat cultivars under post anthesis water deficiency.

Parameters[▲]	Condition	Y	B	HI	1000GW	NGS	NSP	SL	PL	PH	DTF	DPM	GFP	FS	NFS
Y	Water	1													
	Stress	1													
B	Water	0.84**	1												
	Stress	0.55	1												
HI	Water	0.53	-0.01	1											
	Stress	0.36	-0.58	1											
1000GW	Water	0.13	0.16	-0.06	1										
	Stress	0.59	-0.21	0.84**	1										
NGS	Water	0.26	0.05	0.46	-0.76**	1									
	Stress	-0.42	0.07	-0.46	-0.69*	1									
NSP	Water	0.67*	0.82**	-0.07	0.56	-0.45	1								
	Stress	0.20	0.41	-0.28	0.05	-0.55	1								
SL	Water	0.38	0.54	-0.10	-0.52	0.64	0.12	1							
	Stress	-0.02	0.44	-0.45	-0.36	0.74*	-0.33	1							
PL	Water	0.50	0.51	0.16	0.01	0.47	0.23	0.77**	1						
	Stress	0.25	0.57	-0.35	-0.24	0.50	-0.37	0.75**	1						
PH	Water	0.10	0.40	-0.43	-0.40	0.35	0.06	0.87**	0.61	1					
	Stress	0.06	0.63	-0.59	-0.38	0.50	-0.04	0.90**	0.70*	1					
DTF	Water	0.18	0.01	0.36	-0.43	0.70*	-0.22	0.63	0.63	0.44	1				
	Stress	-0.15	0.40	-0.56	-0.47	0.46	-0.01	0.47	0.67*	0.37	1				
DPM	Water	0.27	-0.07	0.65*	0.04	0.43	-0.10	0.15	0.50	-0.10	0.77**	1			
	Stress	-0.12	0.15	-0.27	-0.45	0.42	-0.16	0.11	0.50	-0.02	0.77**	1			
GFP	Water	0.24	-0.11	0.63	0.51	-0.05	0.07	-0.42	0.12	-0.62	0.16	0.75**	1		
	Stress	-0.06	-0.09	0.04	-0.30	0.26	-0.23	-0.20	0.21	-0.32	0.36	0.87**	1		
FS	Water	0.28	0.12	0.39	-0.81**	0.97**	-0.33	0.71*	0.44	0.38	0.72*	0.37	-0.16	1	
	Stress	-0.50	-0.07	-0.37	-0.60	0.96**	-0.47	0.70*	0.31	0.43	0.38	0.29	0.14	1	
NFS	Water	-0.37	-0.09	-0.61	0.72*	-0.95**	0.35	-0.51	-0.33	-0.16	-0.67*	-0.52	-0.11	-0.93**	1
	Stress	0.31	-0.17	0.50	0.77**	-0.91**	0.51	-0.53	-0.49	-0.34	-0.49	-0.58	-0.48	-0.79**	1

[▲]Y: Grain Yield (g/m^2), B: Biomass (g/m^2), HI: Harvest Index (%), 1000GW: 1000 Grain Weight (g), NGS: Number of Grain Per Spike, NSP: Number of Spike Per m^2, SL: Spike Length (cm), PL: Peduncle Length (cm), PH: Plant Height (cm), DTF: Days to Flowering, DPM: Days to Physiological Maturity, GFP: Grain Filling Period, FS: Fertile Spikelet, NFS: Non Fertile Spikelet.

[*] And [**]Significant at the 5 and 1 percent levels, respectively and another no significant.

Peduncle length had significant and positive correlation with spick length, plant height, number of grains spike^{-1} and spikelet fertility and also under post anthesis water deficiency, there were significant and positive correlation between peduncle height with plant height and days from sowing till anthesis.

The findings of the current study are consistent with those of Mir-Akhuri, [28] who found that there were positive and significant correlation between grain yield and spike length, awn length, number of grains spike^{-1}, number of spicklets spike^{-1} and grain weight. But in present study, there were no significant relationship between grain yield and spike length of studied cultivars.
Between control and post anthesis water deficiency conditions In terms of days from sowing until to maturity and grain filling period there were significant differences. Post anthesis water deficiency decreased days from sowing until to maturity and grain filling period (Tables 2, 3). Water deficit reduced duration of growth in different cultivars an average from 206 days under control treatment to 197 days in water deficiency. In addition water deficiency caused shortening of grain growth duration from 38 days in control treatment to 28 days. Probably one of the main reasons for reduction of grain weight and gain yield under post anthesis water deficiency was reduction in grain growth duration. Reduction of grain growth duration and thereby reduction in grain weight and yield production under post anthesis water deficiency previously reported by Gooding et al, [21] and Koocheki et al, [25]. In terms of plant growth duration, Pishtaz cultivar had the highest (204 days) and Chamran cultivar had the lowest (198 days) values. In terms of grain growth duration, Pishtaz and Pishgam cultivars had the longest (35 days) and Chamran, Zarin and DN-11 had the shortest (31 day) duration (Table 2, 3).

Assessment of drought resistance indices

In order to study different cultivars in terms of their drought tolerances based on drought tolerance indices , to determine the best index and also drought-tolerant cultivars, grain yield under control and post anthesis water deficiency were used (Table 5). Evaluation of cultivars by using Stress Susceptibility Index (SSI) test materials classified based only upon of resistance and susceptibility to stress. In the other words, by using these indices can be select sensitive and tolerant cultivars regardless of their yield potential under control and water deficit. Then, this index has a very high efficiency to find tolerant cultivars [20, 31, 46, 48].

Table 5. Estimation of tolerance and susceptibility indices for grain yield in different improved wheat cultivars under post anthesis water deficiency in the west of Iran

Number	Cultivars	Yp*	Ys	SSI	STI	GMP	TOL	MP	HARM
1	Bahar	724.0	474.9	1.014	0.699	586.38	249.06	599.45	573.58
2	Parsi	692.3	437.3	1.086	0.615	550.22	255.07	564.80	536.00
3	Pishtase	705.2	496.8	0.871	0.712	591.91	208.37	601.01	582.95
4	Pishgam	717.6	445.8	1.116	0.650	565.63	271.77	581.72	549.98
5	Chamran	561.9	447.0	0.602	0.510	501.17	114.88	504.45	497.91
6	Zarin	724.0	447.5	1.125	0.658	569.21	276.45	585.75	553.14
7	Sivand	782.7	496.5	1.078	0.789	623.36	286.23	639.58	607.56
8	Marvdasht	656.1	410.8	1.102	0.548	519.18	245.28	533.47	505.28
9	DN-11	750.2	515.1	0.923	0.785	621.64	235.04	632.65	610.82
Mean		701.6	463.5	0.991	0.663	569.86	238.02	582.54	557.47

**Yp: Potential Yield (g/m²), Ys: Stress Yield (g/m²), SSI: Stress Susceptibility Index, STI: Stress Tolerance Index, GMP: Geometric Mean Productivity, TOL: Tolerance, MP: Mean Productivity.*

Researchers believe that the best index for screening stress tolerant cultivars for farmers, It is an indicator that in both control and stress conditions select high yielding cultivars [6, 14]. Thus, by using correlation coefficient between grain yield under water deficiency stress and control with results of stress tolerance indices can be evaluate them and select the best index and cultivar for production of high yield in both situation. The results of correlation coefficients between indices and grain yield under stress and control treatments are shown in Table 6.

The obtained results showed that highest correlations between higher grain yield under water stress and indices in this study there are with Harmonic Mean (HARM), Stress Tolerance Index (STI) and the Geometric Mean Performance (GMP) indices. This finding is in agreement with Sadeghzade-Ahari [39], Aghaee-Sarbarzeh and Rostaee [1] and Talebi et al, [48]. The results of the correlation coefficients between grain yields under control treatment with studied indices showed that Mean Production (MP), Geometric Mean Performance (GMP) and Stress Tolerance Index (STI) had the highest correlation coefficients with high grain yield under control treatment (Table 6). So there are positive and significant correlations between grain yields of cultivars in controlled and post anthesis water deficit conditions with STI, GMP and MP indices. The results of this study show that mentioned indices have ability to detect and identify high yielding cultivars in both control and post anthesis water deficiency stress environment. Therefore, these indices can be introduced as the best indicators for evaluating resistant cultivar for practical use. This study produced results which corroborate the findings of a great deal of the previous work in this field such as: Farshadfar et al. [13], Ashkani et al, [5], Talebi et al, [48], Shiri et al, [45] and Gravandi et al, [22].

Table 6. Correlation coefficients among drought tolerance and susceptibility indices and grain yield for investigated improved wheat cultivars in the west of Iran

	Ys*	Yp	SSI	STI	GMP	TOL	MP	HARM
Ys	1							
Yp	0.572	1						
SSI	-0.229	0.664*	1					
STI	0.866**	0.906**	0.286	1				
GMP	0.856**	0.914**	0.306	0.999**	1			
TOL	0.040	0.842	0.960**	0.534	0.551	1		
MP	0.805**	0.947**	0.391	0.993**	0.996**	0.625	1	
HARM	0.901**	0.871**	0.215	0.997**	0.995**	0.469	0.982**	1

**Yp: Potential Yield, Ys: Stress Yield, SSI: Stress Susceptibility Index, STI: Stress Tolerance Index, GMP: Geometric Mean Productivity, TOL: Tolerance, MP: Mean Productivity.*
** and **: Significant at the 5 and 1 percent levels, respectively.*

According to the results were told, under both control and post anthesis water deficiency the highest MP was belonging to the Sivand and DN-11 cultivars with 640 and 633 g/m^{-2} respectively. Based on the results, Chamran, Pishgam and DN-11 cultivars had the lowest amount of SSI. So these cultivars have the lowest sensitivity or the highest resistance to post anthesis water deficiency in this experiment. Chamran cultivar had the lowest value of the TOL index. Therefore among evaluated cultivars, based on these indices probably Chamran cultivar was the most tolerant cultivars to post anthesis water deficit [43] and is appropriate for using in physiological research and breeding programs to identify mechanisms of resistance to dehydration stress and transfer them to cultivars with high production potential in control conditions, but sensitive to water deficit (Table 6). Based on this concept which, whenever in terms of the MP, STI and GMP indices is superior, in both control and stress treatments has higher grain yield, on this basis Sivand cultivar is probably the best and its cultivation by farming in these situation with possibility of occurrence post anthesis water deficiency stress in addition to producing a higher grain yield than other cultivars also associated with a lower risk. In this respect the DN-11 cultivar is in the next rank.

Acknowledgements
Authors gratefully acknowledge the funding from the Razi University of Iran through Grant.

REFERENCES

[1] M Aghaee-Sarbarzeh and M Rostaee, The 10th Iranian Congress of Crop Sciences, **2008**, 217.
[2] A Ahmadi, M Joudi, A Tavakoli and M Ranjbar, *J Crop Production and processing*, **2009**, 12,155-166.
[3] H Akbari Moghaddam, GR Etesam, SA Koohkan, H Rostami and GA Keikha, 7th Iranian Crop Science Congress, **2002**, 735.
[4] LA Araus, GA Slafer, MP Reynolds and C Royo, *Ann Bot*, **2002**, 89 , 925-940.
[5] J Ashkani, H Pakniyat and V Ghotbi, *Pak. J. Bio. Sci*, **2007**, 10, 14, 2320-2326.
[6] A Blum, *Euphytica*, **1998**, 100, 77-83.
[7] RE Brevedan and DB Egli, *Crop Sci*, **2003**, 43, 2083-2088.
[8] P Debaeke and A Abdellah, *Europ J Agronomy*, **2004**, 21, 433-446.
[9] B Ehdaie, GA Alloush, MA Madore and JG Waines, *Crop Sci*, **2006**, 46, 2093–2103.
[10] JE Ephrath and JD Hesketh, *Photosynthetica*, **1991**, 25, 607-619.
[11] L Ercoli, L Lulli, M Mariotti, A Masoni and I Arduini, *European Journal of Agronomy*, **2007**, 28, 138-147.
[12] S Fard, AM Bakhshandeh and A Naderi, 6th Iranian Crop Sciences Congress. **2000**, 676.
[13] E Farshadfar, B Jamshidi, K Cheghamirza, JA Teixeira da Silva, *Ann Biol Res*, **2012**, 3, 1, 465-476.
[14] A Farshadfar, M Zamani, M Matlabi and A Emamjome, *Iranian Journal of Agriculture Science*, **2001**, 32, 65-77.
[15] GCJ Fernandez, Proceeding of International symposium, **1992**, 257-270.
[16] RA Fischer and R Maurer, *Aust J Agric Res*, **1978**, 29, 897-912.
[17] A Galle, I Florez-Sarasa, A Thameur, R Paepe, J de Flexas and M Ribas-Carbo, *J Exp Bot*, **2010**, 61, 765–775.
[18] S Gan and RM Amasino, *Plant Physiol*, **1997**, 113, 313-319.
[19] T Gebbing, H Schnyder and W Kuhbauch, *Plant Cell Env*, **1999**, 22, 851-858.
[20] M Golabadi, A Arzani and S Maibody, *Afr J Agric Res*, **2006**, 5, 162-171.
[21] MJ Gooding, RH Ellis, PR Shewry and JD Schofield, *J of Cereal Sci*, **2003**, 37, 295-309.
[22] M Gravandi, A Farshadfar and D Kahrizi, *Seed and Plant Improvment Journal*, **2011**, 26, 252-233.
[23] H Heidari Sharifabad, The 10th Iranian Congress of Crop Sci, **2008**, 18-20.
[24] T Kobata, JA Palta and NC Turner, *Crop Sci*, **1992**, 32, 1238-1242.
[25] AR Koocheki, A Yazdansepas and HR Nikkhah, *Iranian Journal of Crop Sciences*, **2006**, 8, 14-29.
[26] Z Liang, F Zhang, M Shao and J Zhang, *Botanical Bulletin of Academia Sinica*, **2002**, 43, 187-192.

[27] DE Martinez, VM Luquez, CG Bartoli and JJ Guiamét, *Physiol Plant*, **2003**, 119, 1–7.
[28] N Mir-akhuri, MS Thesis, Tehran University. Karaj, Iran, **2001**.
[29] J Mitra, *Current Science*, **2001**, 80: 758-763.
[30] GLF Moral, Y Rharrabti, D Villegas and C Royo, *Agron J*, **2002**, 95, 266–274.
[31] A Naderi, I Majidi-Harvan, A Hashemi-Dezfoli, A Rezaee and G Normohamadi, *Seed and Plant Improvment Journal*, **1999**, 15, 390-402.
[32] J Passioura, *J Exp Bot*, **2007**, 58, 113–117.
[33] P Pecciti and P Annicchiarico, *Euphytica*, **1998**, 99, 9-15.
[34] S Rajaram and M Van Ginkle, Mexico, 50 years of international wheat breeding, Lvoisier pub, Paris, France, **2001**.
[35] M Reynolds, MJ Foulkes, GA Slafer, P Berry, MAJ Parry, JW Snape and WJ Angus, *Journal of Experimental Botany*, **2009**, 60, 1899-1918.
[36] RA Richards, GJ Rebetzke, AG Condon and AF van Herwaarden, *Crop Sci*, **2002**, 42, 111-131.
[37] DJ Rodriguez, J Romero-Garcia, R Rodríguez-Garcia and JAL Sánchez, Trends New Crops New Use, **2002**, 1, 143-149.
[38] AT Rosielle and J Hamblin, *Crop Sci*, **1981**, 21, 493.
[39] D Sadeghzade-Ahari, *Iranian Journal of Crop Sciences*, **2006**, 8, 30-45.
[40] M Saeidi, F Moradi, A Ahmadi, R Spehri, G Najafian and A Shabani, *Iranian Journal of Crop Sciences*, **2010**, 12, 4, 392-408.
[41] A Sanjari-Pirevatlou and A Yazdansepas, *J Agric Sci Technol*, **2008**, 10, 109-121.
[42] MK Shafazadeh, A Yazdansepas, A Amini and MR Ghannadha, *Seed and Plant Improvment Journal*, **2004**, 20, 57-71.
[43] NH Shah and GM Paulsen1, *Plant and Soil*, **2003**, 257, 219–226.
[44] K Shamsi, S Kobraee, B Rasekhi, *Ann Biol Res*, **2011**, 2, 372-377.
[45] M Shiri, M Valizadeh, E Magjidi, A Sanjari and A Gharib-Eshghi, *EJCP*, **2010**, 3, 3, 153-171.
[46] A Sio-Se Mardeh, A Ahmadi, K Poustini and V Mohammadi, *Field Crop Res*, **2006**, 98, 222-229.
[47] M Tagvai, M Chai-Chi, F Sharif zade and A Ahmadi, *Iranian Journal of Agricultural Sciences*, **2007**, 38, 1, 67-78.
[48] R Talebi, F Fayaz and AM Naji, *Plant Physiol*, **2009**, 35, 64-74.
[49] A Tavakoli, A Ahmadi and H Alizade, *Iranian Journal of Field Crop Science*, **2009**, 40, 1, 197-211.
[50] MJ Thomas Robertson, S Fukai and MB Peoples, Field Crop Res, **2004**, 86, 1, 67-80.
[51] RM Trethowan and M Reynolds, Drought resistance: Genetic approaches for improving productivity under stress, Springer Pub, The Netherlands. **2007**, pp 289-299.
[52] M Van Ginkel, DS Calhoun, G Gebeyehu, A Miranda, C Tian-You, R Pargas Lara, RM Trethwan, K Sayre, J Crossa and S Rajaram, Plant traits related to yield of wheat in early, late, and continuos drought conditions, Kluwer Publishers, Netherlands, **1998**, pp 167-179.
[53] IF Wardlaw, *Ann of Bot*, **2002**, 80, 469-476.
[54] A Winkel, *Vortage-Fur-Pflanzenzvchtuny*, **1982**, 16, 368-375.
[55] J Yang and Zang, *New Phytol*, **2006**, 169, 223–236.