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Study of Water Stress Effects in Different Growth Stages on Yield and Yield Components of Different Rice (*Oryza sativa* L.) Cultivars

[1]Zinolabedin Tahmasebi Sarvestani, [1]Hemmatollah Pirdashti,
[1]Seyed Ali Mohammad Modarres Sanavy and [2]Hamidreza Balouchi
[1]Department of Agronomy, Faculty of Agriculture, Tarbiat Modares University, Iran
[2]Department of Agronomy, Faculty of Agriculture, Yasuj University, Iran

Abstract: A field experiment was conducted during 2001-2003 to evaluate the effect of water stress on the yield and yield components of four rice cultivars commonly grown in Mazandaran province, Iran. In northern Iran irrigated lowland rice usually experiences water deficit during the growing season include of land preparation time, planting, tillering stage, flowering and grain filing period. Recently drought affected 20 of 28 provinces in Iran; with the southeastern, central and eastern parts of the country being most severely affected. The local and improved cultivars used were Tarom, Khazar, Fajr and Nemat. The different water stress conditions were water stress during vegetative, flowering and grain filling stages and well watered was the control. Water stress at vegetative stage significantly reduced plant height of all cultivars. Water stress at flowering stage had a greater grain yield reduction than water stress at other times. The reduction of grain yield largely resulted from the reduction in fertile panicle and filled grain percentage. Water deficit during vegetative, flowering and grain filling stages reduced mean grain yield by 21, 50 and 21% on average in comparison to control respectively. The yield advantage of two semidwarf varieties, Fajr and Nemat, were not maintained under drought stress. Total biomass, harvest index, plant height, filled grain, unfilled grain and 1000 grain weight were reduced under water stress in all cultivars. Water stress at vegetative stage effectively reduced total biomass due to decrease of photosynthesis rate and dry matter accumulation.

Key words: Rice genotypes, yield, water stress, grain filling, flowering

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for more than two-third of the world's population (Dowling *et al*., 1998). Stable and high yields of rainfed lowland rice are important for food security in many of the subsistence farming systems in Asia (Cooper, 1999). About 7.5% of total rice production comes from irrigated lowland production (Bouman and Toung, 2001). It has been estimated that more than 200 million tons of rice are lost every year due to environmental stresses, diseases and insect pests (Herdt, 1991; Chen and Murata, 2002). Drought stress is a major constraint for about 50% of the world production area of rice. Yield losses from drought in lowland rice can occur when soil water contents drop below saturation (Bouman and Toung, 2001). Rice crops are susceptible to drought, which causes large yield losses in many Asian countries (Bouman and Toung, 2001; Pantuwan *et al*., 2002a), however, some genotypes are more drought resistance than others, out-yielding those exposed to the same degree of water stress. The development of drought resistant cultivars may be assisted if mechanisms of drought resistance are known. Iran is a semi-arid country with 240 mm annual precipitation and 600,000 ha paddy field area; all of them are irrigated lowland rice with continuously submerge irrigation regime by keeping 3-5 cm standing water all of the growing period. Rice is the second main consumed in Iran, with wheat being the main staple for most of the population and Capital rice consumption per year is 36-38 kg. Two northern province near the Caspian Sea bank with annual precipitation of 700-1000 mm covering 70-80% of paddy filed cultivation area in Iran. Unfortunately the main parts of rainfall are out of rice cultivation season. Irrigation dominates water use in Iran and surface water storage has been increased by construction of numerous multi-purpose dams and reservoirs along rivers flowing from the Zagros and Elburz mountains. In northern Iran irrigated lowland rice usually experiences water deficit during the growing season include of land preparation time, planting, tillering stage, flowering and grain filing period. Recently drought

Corresponding Author: Zinolabedin Tahmasebi Sarvestani, Department of Agronomy, Faculty of Agriculture, Tarbiat Modares University, P.O. Box 14115-336, Tehran, Iran

affected 20 of 28 provinces in Iran, with the southeastern, central and eastern parts of the country being most severely affected (Reynolds, 2001). Iranian rice cultivars consist of local and improved variety so that, local variety are low yield (less than 4 t ha^{-1} based on paddy), tall plant, high quality, generally short-term maturity (less than 90 days from transplanting to harvesting) and marketable with high price; meanwhile, improved variety are high yield (more than 6 t ha^{-1} based on paddy), short plant height, mid and long-term maturity (110-130 days), medium quality and cheaper than local variety. There is three methods for variety improvement in Iran include of: Selection; Introduction from IRRI and breeding techniques. Water stress may occur at different growth stages and be of varying duration and intensities, thereby affecting growth and yield. Different reports showed that rice grain yield affected by water stress. If water stress occurs at tillering stage, caused to reduce number of reproductive tiller and panicle per hill (Wopereis *et al*., 1996). However some experiment showed that water stress between panicle initiation and flowering stage to cause reduce number of grain per panicle and when water stress event at flowering and early grain filling period, grains sterility and panicles fertility will be reduce (Boonjung and Fukai, 1993; Garrity and O' Toole, 1994). Water stress after the flowering stage caused to reduce grain weight (Bouman and Tuong, 2001). However, it's showed that different varieties performance vary response to water stress, some of them are susceptible at vegetative stage and other at flowering and grain filling period (Pantuwan *et al*., 2002a). There is very little information on drought resistance of rice genotypes in Iran used in lowland production. This study was carried out to describe the differences in yield and yield component of commonly grown rice cultivars when crops were stressed at different growth stages.

MATERIALS AND METHODS

A field experiment was carried out in Rice Research Institute of Iran-Deputy of Mazandaran Province (Amol city) located in the north of Iran (52°22? N, 36°28? E and 28 masl) during 2001-2003 at the rice cultivation season with mean temperature 16.4, 22.9, 25.9, 27.3, 25.4°C from April to September, respectively. The research field had a loamy-silty soil and moderate climate (Table 1).

This experiment was laid out to evaluate varietal performance of four rice cultivars in terms of yield and yield components as affected by water stress. The experiment was designed as a split-plot, factorial in a randomized complete block design with three replications. Main-plots were four water stress regimes (water stress in vegetative stage, water stress in flowering stage, water stress in grain filling stage and control or no water stress). Subplots were 3×4 m with 0.5 m and main plots with 1 m apart. Aimed at water stress is shortage irrigation up to 20 days for reducing saturate water so that narrow crack will appear in the soil surface. The control was irrigated as required to ensure and keep a 2-5 mm level of standing water throughout crop growth. Plants in water stress treatments were grown under favorable water conditions with supplementary surface irrigation throughout the crop cycle while irrigation was interrupted to induce drought stress at around vegetative, flowering and grain filling stages. Sub-plots were four contrasting cultivars, Tarom, Khazar, Fajr and Nemat (Table 2). A mixed commercial fertilizer was applied at the rate of 92 kg N ha^{-1},44 kg P ha^{-1} and 83 kg K ha^{-1}; all of phosphorous, potassium and half of nitrogen fertilizer applied at basal and other 50% nitrogen fertilizer has applied as a top dressing at panicle initiation. Making nursery and management for raising seedling have done with lowland traditional wet nursery. Seedlings 30-35 days old (4-5 leaves stage) were used for transplanting and three seedlings were transplanted to each hill, spaced at 25×25 cm. Since, growth duration of cultivars were different together, for synchronously of cultivars flowering, Nemat transplanting date (as a long-term variety) was 10 days earlier than others (April-25) and Tarom transplanting date was later than others as a short term variety (May-5). Plant height was measured on 10 randomly selected hills by measuring the distance from

Table 1: Soil characteristic of experimental field and weather condition

Soil depth	pH	Organic matter (%)	Phosphorous (ppm)	Potassium (ppm)	Sand	Silt	Clay	Soil texture
0-25	7.1	2.2	20	150	27	49	24	Loamy silty

	Apr.-May	May-June	June-July	July-Aug.	Aug.-Sep.
Mean temperature (2002)	16.4	22.9	25.9	27.3	25.4
Mean temperature (2003)	17.0	22.4	25.1	25.9	25.2

Table 2: Description of cultivars under experiment

Name of variety	Kind of variety	Maturity	Yield	Palatability	Range of adaptation
Tarom	Local	Short-term	Low	Very good	Wide
Khazar	Improved	Medium	Medium	Good	Wide
Fajr	Improved	Medium	High	Good	Low
Nemat	Improved	Long-term	High	Medium	Low

the soil surface to the tip of the highest panicle within each hill. Grain yield was determined from a harvest area of 4 m^2 (64 hills) adjusting to 14% moisture content and yields refer to rough grain yield. All plants from the harvested area were dried at 70°C for total dry matter determination and harvest index was calculated as grain yield per total dry matter. Panicle number per m^2 was determined at dough stage. To estimate the fertility of panicles, five randomly sampled panicles per plot were counted for filled and unfilled grains and the percentage of filled grains was calculated. Data were analyzed by Analysis of Variance (Proc Anova). The 2-year data underwent a repeated-measures data analysis by using a combined analysis of variance across years. All statistical tests were carried out using the Statistical Analysis System (SAS, 1997).

RESULTS AND DISCUSSION

Water deficit during vegetative, flowering and grain filling stages reduced mean grain yield by 21, 50 and 21% respectively in comparison to control. Grain yield differed among the four cultivars. In two years, Nemat had the largest grain yield in the control treatment. When drought stress was imposed at the vegetative stage, the grain yield of Nemat, Khazar and Fajr were significantly reduced. Nemat had the highest reduction (25%), while Tarom had only a slight reduction (14.5%). Bouman and Toung (2001) showed that different cultivars might have different responses to the same drought stress timing and intensity. Compared to the well-watered conditions, panicle number was only slightly reduced in Tarom (Table 3). Total biomass, harvest index, plant height, filled

Table 3: Grain yield and plant parameters of four rice cultivars grown under four water stress treatments in north of Iran

		Grain yield[A]		Total biomass		Harvest index		Plant height	
	Water	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Cultivars	stress[B]	(kg ha^{-1})						(cm)	
Tarom	W0	4.7ef	4.9fg	12.7b	12.8bc	0.37f	0.38d	154.1a	154.8a
Tarom	W1	4.0h	4.2i	9.5f	9.6f	0.42e	0.44bc	129.16c	129.8b
Tarom	W2	2.5l	2.7l	11.7c	11.8c	0.21l	0.23f	134.6bc	153.2a
Tarom	W3	4.1gh	4.6h	12.1b	12.2c	0.34g	0.38d	132.7bc	153.4a
Khazar	W0	5.5c	5.9c	13.0a	13.1b	0.42de	0.45b	128.9cd	128.6b
Khazar	W1	4.5fg	4.7gh	10.1ef	10.3ef	0.44d	0.45ab	110.9e	111.6d
Khazar	W2	2.6l	2.7l	11.7c	11.7cd	0.22k	0.24f	112.8de	127.8b
Khazar	W3	4.5f	4.7g	11.9bc	12.3c	0.37f	0.38d	109.7e	128.1b
Fajr	W0	6.4b	6.6b	12.9ab	13.4b	0.50a	0.49a	134.8b	117.6c
Fajr	W1	5.0de	5.0f	10.3e	10.4e	0.48b	0.49a	113.2d	99.60e
Fajr	W2	3.2k	3.2l	11.5cd	11.5d	0.28i	0.28e	115.3d	116.0c
Fajr	W3	4.9e	4.9f	11.7c	12.1c	0.42e	0.41cd	110.9e	115.2c
Nemat	W0	7.1a	7.1a	13.7a	15.3a	0.51a	0.47a	131.7c	113.0cd
Nemat	W1	5.3cd	5.3e	10.8de	10.9de	0.48b	0.49a	109.8e	92.7f
Nemat	W2	3.6i	3.6k	11.8c	11.9c	0.30h	0.30e	110.8e	107.8d
Nemat	W3	5.6c	5.7d	12.1b	12.1c	0.46c	0.47a	110.9e	113.4c
CV (%)		26.83	26.3	9.94	12.28	24.26	22.46	15.12	15.02
Year mean[C]		4.60	4.8a	11.7a	12.0a	0.39a	0.40a	122.6a	121.1a

		Panicle-bearing tiller		Filled grain		Unfilled grain		1000 grain wt.	
	Water	Year 1A	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Cultivars	stress[B]	(No. m^{-1})		(No. per panicle)				(g)	
Tarom	W0	14.8c	15.5c	91.8b	92.4e	6.9g	6.3i	24.3e	24.7f
Tarom	W1	10.4ef	10.8e	90.6bc	91.2ef	7.5g	8.1i	24.0ef	24.3f
Tarom	W2	14.4c	14.9cd	57.0e	47.9j	18.4f	19.4h	23.3fg	23.7f
Tarom	W3	14.3cd	15.0c	71.4d	71.8c	17.2f	18.0h	21.0h	20.7g
Khazar	W0	12.1de	12.6d	118.9a	119.7b	55.8c	55.4c	30.0bc	30.3b
Khazar	W1	8.86f	9.3e	118.7a	119.3b	56.6c	56.4c	30.0b	30.3b
Khazar	W2	11.1e	11.9de	64.1bc	57.9hi	61.7b	62.5b	29.3c	29.7cd
Khazar	W3	10.5e	10.7e	97.5b	98.1de	75.9a	75.6a	25.0e	25.3e
Fajr	W0	24.3a	25.0a	128.1a	128.4a	30.9e	30.5g	26.7d	26.7de
Fajr	W1	16.8bc	17.8b	126.1a	127.2a	31.6e	31.2g	26.7d	27.0c
Fajr	W2	16.8b	17.3bc	56.6e	64.7h	53.6c	53.7e	26.3d	26.7d
Fajr	W3	16.8b	17.6b	101.2b	101.5d	57.1c	57.7c	22.7g	23.0e
Nemat	W0	24.6a	25.7a	115.5a	116.4b	37.8d	37.5f	32.3a	32.0a
Nemat	W1	18.6b	19.4b	47.8f	114.0g	38.1d	38.4f	32.0a	32.0a
Nemat	W2	18.7b	19.6b	56.6e	57.5i	55.2c	55.2de	30.7b	31.3ab
Nemat	W3	18.7b	18.9b	87.8c	88.1f	64.8b	64.9b	25.0e	25.3de
CV (%)		29.94	30.01	28.89	28.74	50.31	50.13	12.96	12.87
Year mean[C]		15.7a	16.4a	92.9a	93.5a	41.8a	41.9a	26.8a	27.1a

A: Common letter(s) within the column do not differ significantly at 5% level of significance analyzed by DMRT, B: W0 Control; W1: Water stress at vegetative stage; W2: Water stress at flowering stage; W3: Water stress at grain filling stage, C: Common letter(s) within the row do not differ significantly at 5% level of significance analyzed by DMRT grain, unfilled grain and 1000 grain weight were reduced under water stress in all cultivars. Water stress at vegetative stage effectively reduced total biomass due to decrease of photosynthesis rate and dry matter accumulation (Table 3).

The combine analysis of variance showed that the effect of year on yield is significant and yield at second year is more than first year due to increase number of tillers and harvest index at second year (Table 4). There is significant interaction between water stress and kind of varieties (1% level-Duncan test) so that cultivar of Nemat had a highest yield and total biomass at control treatment and cultivars of Tarom and Khazar had a lowest yield at treatment of water stress at flowering stage (Table 5).

Rahman *et al.* (2002) reported that plant height, tiller number, panicle number, panicle length, number of filled grains per panicle, 1000-grain weight, harvest index (HI), total dry matter (TDM) and yield were decreased with stress. Grain yield was reduced dramatically in all cultivars with drought starting at panicle initiation or at flowering. Water stress at flowering reduced grain yield more than other water stress treatments. The reduction in yield largely resulted from the reduction in fertile panicle number and filled grain percentage. Fukai *et al.* (1999) reported that maintenance of leaf water potential just prior to flowering is associated with higher panicle water potential, reduced delay in flowering time and reduced spikelet sterility and hence contributes to higher yield. On the other hands, yield losses from the normal level due to water stress are useful in assessing drought resistance. The different variety has differently drought resistance mechanism, for a variety, which is also different, at the different stages. However, the complex drought resistance occurs at any growth stage in crop, with the different response and the different mechanism to drought tolerance (Na *et al.*, 2007). Some researcher reported that grain yield could be drastically reduced (about 60%) if drought occurs during flowering time (Boonjung and Fukai, 1996). Pantuwan *et al.* (2002b) reported that drought stress that developed prior to flowering generally delayed the time of flowering of genotypes and the delay in flowering was negatively associated with grain yield, fertile panicle percentage and filled grain percentage. Genotypes with a longer delay in flowering time had extracted more water during the early drought period and as a consequence, had higher water deficits. They were consistently associated with a larger yield reduction under drought. Castillo *et al.* (1992) reported that draining rice fields at either vegetative or reproductive phases caused significant yield loss. Evaluating the effect of different durations of water stress at various growth stages showed that water stress at any stage would reduce yield (Salam *et al*., 2001; IRRI, 2002). However, the duration of these stresses was more closely related to yield reduction than to stage at which the stress occurred. Islam *et al.* (1994b) observed that yield losses resulting from water deficit are particularly severe when drought strikes at booting stage.

Plant height was significantly affected by water stress at booting, flowering and grain filling stage (Table 3) over the control. This result agrees with Islam *et al.* (1994b), who found that moisture stress reduced plant height under 20% soil saturation at booting and flowering stages. Similar result has also been reported by Islam (1999). The decrease in height might be either due to inhibition of length of cells or cell division by water deficits.

Water stress during vegetative stage reduced tiller number, while stress at the reproductive and grain-filling stage reduced grain number and weight. Rahman *et al.* (2002) also reported that the number of tillers per hill was decreased significantly under moisture stress at different growth stages except that at flowering stage. This agreed with Islam *et al.* (1994a). Bouman and Toung (2001) found that drought before or during tillering reduces the number of tillers and panicle per hill. When late season drought was the main cause of low yield, late-maturity cultivars (such as Nemat) were not suitable as panicle development was severely impaired.

Table 4: The combine analysis of variance on grain yield and plant parameters of different rice cultivars under water stress treatments

Source of variation	Grain yield	Total biomass	Harvest index	Plant height	Effective tillers
Year (Y)	1.39*	1.58ns	0.0031*	242.22**	47.03**
Water stress (W)	77.04**	72.85**	0.437*	3924.75**	233.31**
Y*W	0.046ns	0.084ns	0.00044ns	4.07ns	1.09ns
Variety (V)	20.63**	3.61**	0.095**	18926.27**	1158.54**
Y*V	0.23**	0.029ns	0.0024**	8.42ns	4.25ns
W*V	1.007**	1.28**	0.0045**	74.81**	34.52**

Source of variation	Filled grain	Unfilled grain	Total grain	1000 grain wt.
Year (Y)	34.00ns	0.14ns	38.34ns	3.52ns
Water stress (W)	34155.60**	5400.49**	20575.82*	203.23**
Y*W	0.046ns	2.285ns	6.40ns	0.17ns
Variety (V)	7795.72**	20180.18**	48238.49**	461.09**
Y*V	4.37ns	0.56ns	2.77ns	0.145ns
W*V	238.16**	254.59**	403.52**	6.89**

*Significant different at 0.05 level (Duncan test); **Significant different at 0.01 level (Duncan test); ns: Not significant

Table 5: Interaction effects between water stress treatments and rice cultivars on the grain yield and plant parameters

Water stress	Cultivars	Grain yield ($t\ ha^{-1}$) 2002	Grain yield ($t\ ha^{-1}$) 2003	Total biomass ($t\ ha^{-1}$) 2002	Total biomass ($t\ ha^{-1}$) 2003	Harvest index 2002	Harvest index 2003	Plant height (cm) 2002	Plant height (cm) 2003	Effective tiller 2002	Effective tiller 2003
W0	Tarom	4.71f	4.96f	12.90b	13.04bc	0.36g	0.38e	158.75a	161.98a	15.40c	17.24de
W0	Khazar	5.62cd	5.99c	13.91b	13.25b	0.42e	0.45cd	131.40b	133.06cd	12.55d	13.96fgh
W0	Fajr	6.77b	6.78b	13.08b	13.48b	0.51a	0.50a	116.49c	119.38e	26.04a	26.28a
W0	Nemat	7.24a	7.17a	13.91a	14.45a	0.51a	0.49ab	112.17cd	115.15ef	25.77a	27.28a
W1	Tarom	4.08g	4.37g	9.67f	9.70g	0.42e	0.45cd	132.51b	135.55c	11.05de	11.81hi
W1	Khazar	4.68f	4.77f	10.27e	10.56f	0.45d	0.50a	112.08cd	113.48fg	9.53e	10.95i
W1	Fajr	5.13e	5.22e	10.47de	10.57f	0.49b	0.49ab	96.78e	104.00h	19.06b	20.25bc
W1	Nemat	5.46d	5.49d	10.99d	11.11ef	0.49b	0.49ab	98.46e	98.32i	19.91b	21.25b
W2	Tarom	2.56j	2.73i	11.78c	11.98d	0.21k	0.23g	156.33a	157.06b	15.13c	15.40efg
W2	Khazar	2.64j	2.85i	11.92c	11.99d	0.22k	0.24g	128.08b	130.22d	12.00d	13.06ghi
W2	Fajr	3.19j	3.45h	11.68c	11.64de	0.27j	0.29f	115.13c	116.65d	18.10b	18.62cd
W2	Nemat	3.64h	3.66h	11.92c	12.07d	0.30i	0.30f	107.57d	109.76g	19.91b	22.61b
W3	Tarom	4.10h	4.75f	12.17c	12.28cd	0.33h	0.38e	157.21a	158.66ab	15.03c	16.20ef
W3	Khazar	4.10g	4.80f	12.10c	12.45cd	0.38f	0.38e	130.80b	131.03cd	10.93d	12.06hi
W3	Fajr	4.70f	5.29de	12.03c	12.30cd	0.41e	0.43d	114.08cd	115.98ef	20.01b	18.70cd
W3	Nemat	5.01e	5.77c	12.09c	12.25cd	0.47c	0.47bc	110.90cd	114.42f	19.81b	20.41bc

Water stress	Cultivars	Filled grain/Panicle 2002	Filled grain/Panicle 2003	Unfilled grain/Panicle 2002	Unfilled grain/Panicle 2003	Total grain/Panicle 2002	Total grain/Panicle 2003	1000 grain wt. 2002	1000 grain wt. 2003
W0	Tarom	87.26e	92.93ef	6.88k	6.02h	94.15d	98.95d	24.33g	24.83e
W0	Khazar	119.25ab	120.41bc	53.61ef	53.02d	172.86a	74.43a	30.16bc	30.50b
W0	Fajr	128.28a	129.13a	29.78i	29.68f	158.06b	158.82b	26.83d	26.83cd
W0	Nemat	116.75b	116.92c	34.46h	36.58e	153.21b	153.50b	32.50a	32.16a
W1	Tarom	90.95de	91.82ef	7.43k	7.8h	98.38d	99.61d	24.16gh	24.50ef
W1	Khazar	119.65ab	119.75bc	55.60de	55.65cd	175.25a	175.40a	30.16bc	30.50b
W1	Fajr	126.30a	127.61ab	30.98i	30.43f	157.28b	158.05b	26.83d	27.16c
W1	Nemat	114.68b	114.56c	36.96g	37.70e	151.65b	152.26b	30.16a	32.16a
W2	Tharom	48.15h	48.93i	18.26j	19.05g	66.41e	67.98e	23.33h	23.66f
W2	Khazar	57.14gh	57.88h	59.98c	61.65b	117.40c	119.53c	29.33c	29.83b
W2	Fajr	64.48g	65.16gh	52.56f	52.81d	117.05c	117.96c	26.50de	26.83cd
W2	Nemat	56.98gh	57.88h	54.13ef	53.93cd	117.13c	111.81c	31.00b	31.50a
W3	Tarom	73.61f	73.05g	18.15j	17.26g	97.76d	90.32d	26.66i	21.33g
W3	Khazar	98.16cd	98.66de	74.61a	74.86a	172.78a	173.53a	25.5f	26.00d
W3	Fajr	101.55c	102.00d	56.58d	56.71c	158.13b	158.71b	23.33h	23.83cd
W3	Nemat	88.28e	88.52f	63.96b	63.70b	152.26b	152.22b	25.66ef	26.16cd

Common letter(s) within the column do not differ significantly at 5% level of significance analyzed by DMRT, W0: Control; W1: Water stress at vegetative stage; W2: Water stress at flowering stage; W3: Water stress at grain filling period

Total grain number per panicle was drastically reduced when drought stress occurred at flowering. This reflected the reduced crop growth due to drought during flowering. Rahman *et al.* (2002) and Islam *et al.* (1994a) also showed that the number of filled grains per panicle decreased significantly with the moisture stress at booting, flowering and grains filling stages compared with control. The proportion of unfilled grain in the drought stress at flowering stage was 46% compared with 22% in well-watered (control) conditions.

The 1000-grain weight in the drought stress at grain filling stage was 17% smaller than control. Thus, the yield reduction in drought stress at flowering stage mostly resulted from reduction in total grain number per panicle (increase in unfilled grain and a greatly decreased proportion of filled grain) and 1000-grain weight respectively. Similar results on 1000-grain weight under water stress at booting and flowering stages had been showed by Islam (1999) and Islam *et al.* (1994b). Stress during different growth stages might decrease translocation of assimilates to the grains, which lowered grain weight and increased the empty grains. HI values indicate the efficient translocation of assimilates towards sink. Lower HI values under stress at booting and flowering stages indicate that it was more harmful in translocation of assimilates towards the grains over grains filling stage (Rahman *et al.*, 2002).

It has been argued that under severe drought stress, when yields are reduced to below 50% of those under favorable conditions the relationship between yield under favorable and stress conditions break down (Ceccarelli and Grando, 1991). Results of this experiment suggest that genotypes had no capability in expressing their genetic yield potential under these conditions. It appears that the yield advantage observed under favorable conditions of semi-dwarf cultivars (Fajr and Nemat) which required less assimilate for vegetative organs was not maintained under water-limiting conditions.

The results also suggest that Tarom is drought-tolerant and is able to retain green leaves longer than other cultivars under drought conditions. Retention of green leaves in seedlings under drought conditions has been used as a selection criterion for drought resistance (De Datta *et al*., 1988). Alternatively, cultivars with green leaf retention may process dehydration-tolerance mechanism, which allow the plants to maintain metabolic activity, despite low leaf water potential, for example, as a result of high osmotic adjustment (Fukai and Cooper, 1995). Other experiment also confirmed a positive relationship between green-leaf retention and grain yield among 35 lines (Henderson *et al*., 1995). From the above results it can be concluded that cultivars required for Iranian conditions, where frequent drought develops, are those with appropriate phenological development to escape late drought and an ability to maintain growth during drought that may develop late in the season. Consideration of these characters in plant-breeding programs should increase the efficiency of plant improvement in the region.

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