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PHYSIOLOGICAL CHANGES OF WHEAT VARIETIES UNDER WATER DEFICIT CONDITION

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Abstract

The experiment was carried out at the research field of the Department of Agronomy of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during November 2014 to March 2015 to assess and evaluate the physiological derivations of wheat varieties under water deficit condition. The experiment was laid out in a split plot design comprising two water regimes (irrigated or control and water stress) in main plot and three wheat varieties (BARI Gom 25, BARI Gom 26 and Sourav) in sub-plot with four replications. Surface irrigation was applied into the irrigated plots in total growing season but it was applied in water stress plots up to 21 days after sowing after that irrigation was stopped in water stress plots. It was revealed that studied parameters were significantly influenced by water regimes, variety and their interaction. The xylem exudation rate, light interception, SPAD value, leaf water potential, relative water content, water retention capacity was higher in irrigated condition where canopy temperature, water uptake capacity, water saturation deficit higher in water stress condition.The wheat var. BARI Gom 26 showed the highest PAR, SPAD value, leaf water potential, relative water content, water retention capacity where BARI Gom 25 exhibit lowest under water deficit condition. On the other hand, BARI Gom 25 showd the highest canopy temperature, water uptake capacity and water saturation deficit in water deficit condition. Therefore, considering the physiological performance and other characters BARI Gom 26 could be considered preferably for water shortage condition followed by Sourav where BARI Gom 25 was susceptible one.

Introduction

Wheat (*Triticum aestivum*) is world's most widely cultivated food crop and the second important cereal crop in Bangladesh. It provides 21% of the food calories for more than 4.5 billion peoples in 94 countries of the world (Braun *et al*., 2010). Wheat is grown in *rabi* season from October to March which is characterized by very low or no rainfall in Bangladesh. Most of the farmers grow wheat with irrigation but due to scarcity of water or very low or no rainfall affects the plant growth and productivity (Khaliq *et al*., 1999). Water is necessary for plant growth of different metabolic activities but drought causes disorders at morphological, physiological, biochemical and molecular levels (Saeedipour, 2012). A physiological approach would be the most attractive way to develop new varieties (Araus *et al.,* 2008). Morphological studies have been conducted in Bangladesh to identify drought tolerance wheat varieties for higher wheat production and a major challenge for wheat breeders for several decades. In order to identify suitable varieties for drought prone areas, the mechanisms on water stress tolerance has to be better understood. However, more intensive study is required to understand the mechanisms of drought tolerance of wheat. As such, the present research was conducted to study the physiological changes of wheat varieties under water shortage condition.

Materials and Methods

The experiment was carried out at the research field of the Department of Agronomy of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during November 2014 to March 2015. The experimental site is mixed with some imported alluvium soil from nearby flood plain and acidic in nature. The soil of the experimental field is belonging to Sanla series representing shallow red-brown trace soil type. The climate of the experimental site is subtropical and characterized by scanty rainfall associated with moderately low temperature (21 to 24^0C) and plenty of sunshine during *rabi* season (October to March). The experiment was laid out in a split plot design comprising two water regimes (irrigated or control and water stress or water deficit) in main plot and three wheat varieties (BARI Gom 25, BARI Gom 26 and Sourav) in sub-plot with four replications. After well preparation of land, seeds of @120 kg ha^{-1} were sown in 20 cm line sowing method on 23 November 2014. N-P-K-S @ 100-60-40-20 kg ha^{-1}, respectively was applied in the form of urea, triple super phosphate, muriate of potash and gypsum. Total amount of triple super phosphate, muriate of potash and gypsum were applied during final land preparation. Urea was given in two splits, first split of urea was applied during final land preparation and the rest top dressed at 21 DAS. Intercultural operations such as weeding, thinning, gap filling and netting were done when as required. In case of water shortage plots, surface irrigation was applied up to 21 DAS then it was stopped. Data on soil plant analysis development (SPAD) value, measurement of xylem exudation rate, canopy temperature, light interception, leaf water potential, relative water content, water saturation, retention and uptake capacity were recorded by following procedure: SPAD value was taken from middle portion of the fully developed flag leaf of the tagged plants with Minolta Chlorophyll Meter (Model: SPAD-502, Minolta Co. Ltd., Japan). Xylem exudation rate was measured at anthesis stage using following formulae

$$\text{Xylem exudation rate} = \frac{(\text{weight of wheat} + \text{sap}) - (\text{weight of wheat})}{\text{time (hr)}}$$

Canopy temperature was measured with an infra-red thermometer and measurements were made within 2 hours of solar noon, and in a south-facing direction to minimize sun angle effects as suggested by Turner *et al.* (1986).

Light interception (LI) at the crop canopy was measured at booting, anthesis, grain filling and physiological maturity stages with a Sunfleck Ceptometer (Decagdn Deviceinc., USA) using the following formula

$$\text{Light transmission ratio (LTR)} = \frac{I}{Io} \times 100 \text{ and LI \%} = 100 - \text{LTR}$$

Where, Io=photosynthetically active radiation on the top of the canopy and
I= photosynthetically active radiation at the base of the canopy

Leaf water potential was measured fully expanded flag leaf at booting and anthesis stages using a pressure chamber designed by Scholander *et al.* (1965). Relative water content (RWC) was measured at booting, anthesis and grain filling stages. Turgid weight (TW) was obtained after soaking leaves in distilled water in beakers for 24 hours at room temperature about (20^0C) and under the low light condition of the laboratory. Dry weight (DW) of the leaf was obtained after oven drying the leaf samples for 72 hour at 70^0C. RWC was calculated according to Schonfeld *et al.* (1988):

RWC (%) = [(FW-DW)/ (TW-DW)] Ч100.

Measurement of water saturation deficit (WSD), water retention capacity (WRC) and water uptake capacity (WUC) were calculated as follow by Sangakkara *et al.* (1996):

WSD (%) = (TW-FW)/ (TW-DW) Ч 100, WRC = TW/DW and WUC = (TW-FW)/DW

Where, FW = Fresh weight (mg), DW= Dry weight (mg), TW = Turgid weight (mg)

The collection of data was analyzed statistically and the treatment means were adjudged by LSD Test (Gomez and Gomez, 1984) by package program STATISTIX-10.

Results and Discussion

SPAD value was used to ascertain the onset of senescence and chlorophyll content of leaf over time. According to Manivannan *et al.* (2007) chlorophyll is one of the major components of chloroplasts for photosynthesis which increases biomass production and grain yield (Pandey and Singh, 2010). The SPAD value recorded from 0 days after anthesis (DAA) to 28 DAA under control and water deficit conditions in three wheat varieties shown in figure 1.

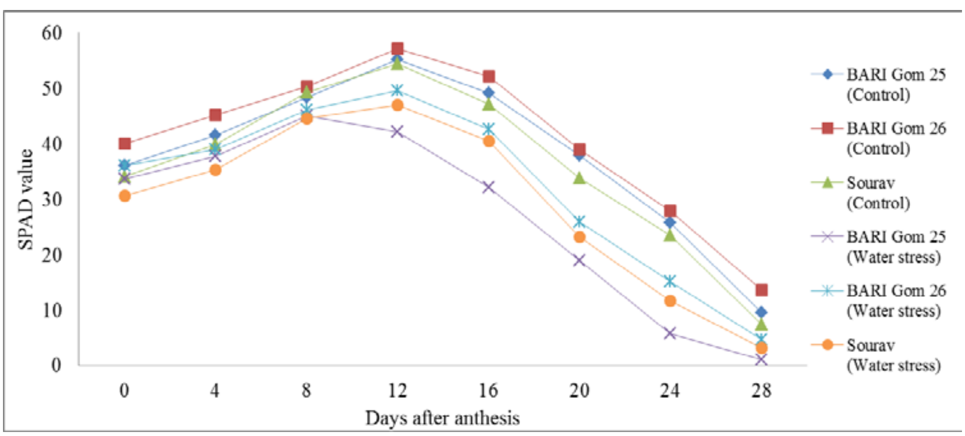

Fig. 1. SPAD values of wheat varieties under water deficit condition

The SPAD value progressively increased up to 12 DAA under control and water deficit conditions then it was decreased in all varieties except BARI Gom 25 where it decreases after 8 DAA. This might be due to forced senescence of leaf irrespective of varieties. At 12 DAA, the highest SPAD value was recorded in BARI Gom 26 under both control (57.13) and water deficit (49.53) condition. The lowest SPAD value was recorded in Sourav (54.45) under control condition but under water deficit condition BARI Gom 25 (42.16) showed the lowest value. Water deficits enhanced the senescence by accelerating loss of leaf chlorophyll and soluble proteins and the loss was more in sensitive one than tolerant one (Saeedipour, 2012). Declined chlorophyll content from 13 to 15% in water-stressed wheat compared with well watered plants (Nikolaeva *et al.*, 2010). Chlorophyll synthesis was inhibited under water deficit conditions. So, with the decreases of chlorophyll content SPAD value also decreases.

Xylem exudation rate is known as the flow of sap through the cut end of a stem against the gravitational forces. The exudation rate varied both control and water stress condition irrespective of varieties shown in figure 2.

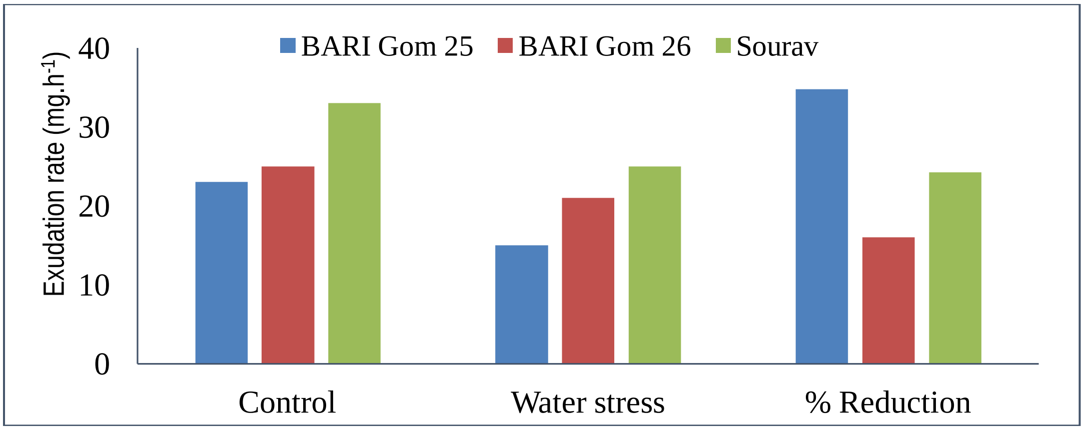

Fig. 2. Xylem exudation rates of wheat varieties under water deficit condition

The highest exudation rate was recorded in the var. Sourav (33 mg h^{-1} and 25 mg h^{-1}) which was followed by the var. BARI Gom 26 (25 mg h^{-1} and 21 mg h^{-1}), while the var. BARI Gom 25 (23 mg h^{-1} and 15 mg h^{-1}) had the lowest exudation rate under both control and water deficit condition. The highest percent of reduction under water stress condition occurred in BARI Gom 25 and the lowest in BARI Gom 26. The results agreed with those obtained by Baque (2006) who reported that exudation rate is higher in control and lower in moisture stress of wheat.

Canopy temperature varied significantly among the varieties due to water stress at anthesis stages. The highest canopy temperature under control condition was recorded in Sourav (30.83^{0}C) which was followed by BARI Gom 26 (27.73^{0}C) and the lowest in BARI Gom 25 (26.23^{0}C) but in water deficit condition the highest canopy temperature was recorded in BARI Gom 25 (34.38^{0}C) which was followed by Sourav (32.73^{0}C) and the lowest in BARI Gom 26 (29.09^{0}C) (Fig. 3).

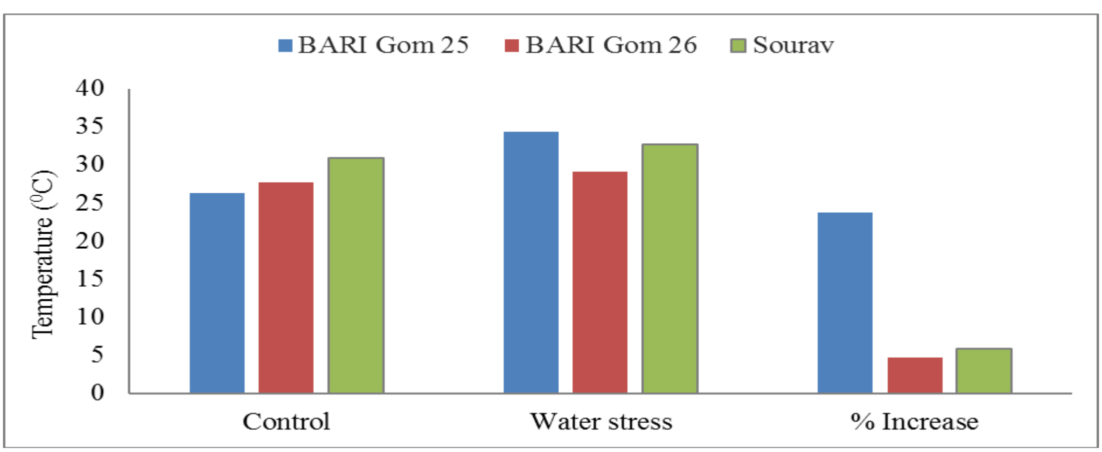

Fig. 3. Canopy temperatures of wheat varieties under water deficit condition

The canopy temperature in wheat varieties increased under water stress condition. This might have occurred due to increased respiration and decreased transpiration as a result of stomatal closure. Similar findings reported by Siddique *et al.* (2000) who reported that leaf temperature in drought stressed wheat plant was higher than in well-watered plants at both vegetative and anthesis stages.

Light interception or interception of photosynthetically active radiation (PAR) at booting, anthesis, grain filling and physiological maturity stage in wheat canopy under variable water regimes varied significantly shown in figure 4.

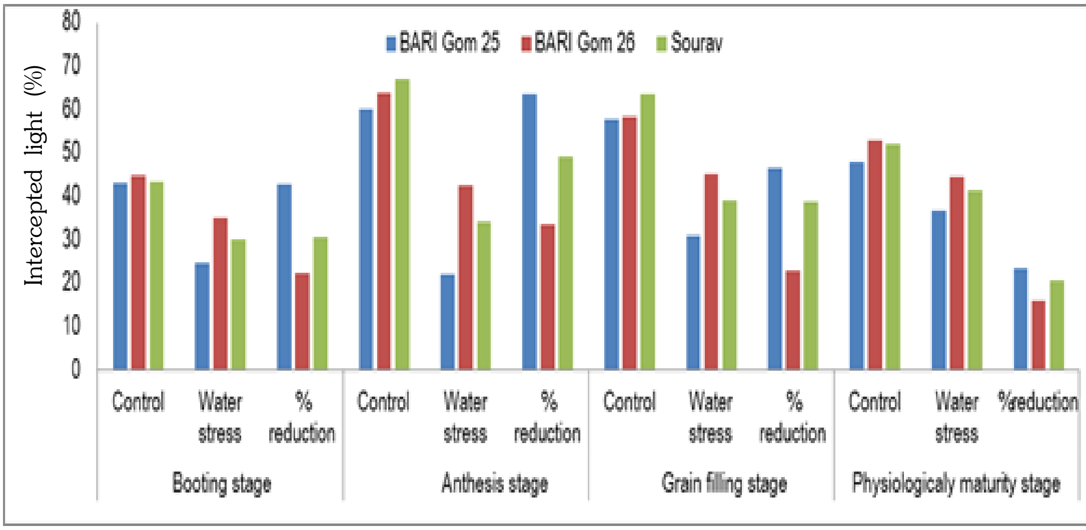

Fig. 4. Intercepted PAR of wheat varieties under water deficit condition

Under control condition the highest amount of light interception was recorded in BARI Gom 26 at booting (44.92%) and physiological maturity stage (52.86%) but at anthesis (67.06%) and grain filling (63.60%) stages showed the highest in Sourav. Incase of water stress, the highest light interception was found in BARI Gom 26 at booting (34.89%), anthesis (42.45%), grain filling (45.04%) and physiological maturity stage (44.42%). At all the growth stages, the lowest light interception was recorded in BARI Gom 25 under both conditions. However the highest reduction under water deficit stress was recorded in BARI Gom 25 while the lowest reduction in BARI Gom 26 at all the growth stages. Canopy radiation interception generally increased throughout the growing season due to increased leaf area. Since the leaves temporarily wilted or rolled under the water stress, the radiation interception ability led to being decreased, as observed in the field. Similar results obtained by Moayedi *et al.*, 2011 and Qamar *et al.,* 2011 that accumulated radiation interception was significantly decreased by limited irrigation than frequently irrigated crop plants.

Leaf water potential (LWP) is considered to be a reliable parameter for quantifying plant water stress response. The leaf water potential is a prominent character that can be selected for improving drought tolerance of different crops (Nayyar *et al.*, 2006). The leaf water potential was significantly influenced and decreased markedly in the studied varieties due to water stress at booting and anthesis stages (Table 1).

Table 1. Leaf water potential of wheat varieties under water deficit condition

Wheat variety	Leaf water potential (-MPa)	
	Booting stage	Anthesis stage

	control	water stress	% reduction	control	water stress	% reduction
BARI Gom 25	0.74	1.07	30.84	0.75	1.58	52.53
BARI Gom 26	0.73	0.82	10.97	0.75	1.01	25.74
Sourav	0.74	0.9	17.78	0.76	1.19	36.13
CV (%)		4.71, 6.19			8.11, 9.75	
$LSD_{(0.05)}$		0.03			0.067	

The highest leaf water potential was recorded in BARI Gom 26 in booting (-0.73 Mpa and -0.82 Mpa) and anthesis stages (-0.75 Mpa and -1.01 Mpa) under both control and water deficit condition, respectively. The lowest leaf water potential was recorded in BARI Gom 25 in booting stage (-0.74 Mpa) but Sourav showed the lowest value in anthesis stages (-0.76 Mpa) under control condition. In case of water stress condition BARI Gom 25 (-1.07 Mpa and -1.58 Mpa) showed the lowest result both at booting and anthesis stages. However, the reduction percent of leaf water potential under water stress was higher in BARI Gom 25 and lower in BARI Gom 26. The changes in water potential in wheat might be due to change in osmotic pressure i.e., the osmotic components of water. Siddique *et al.* (2000) reported that drought stress reduced the leaf water potential from -0.63 MPa in control plant and -2.00 MPa in stressed plants. The results obtained in this study were consistent with the result of Subrahmanyam *et al.* (2006) who reported that water deficit stress caused a significant difference in leaf water potential in the tolerant and susceptible genotypes of wheat.

Relative water content (RWC) indicates that the water status of cells has a significant association with yield and stress tolerance (Almeselmani *et al.*, 2012). It is considered a measure of plant water status, reflecting the metabolic activity in tisshues and used as a most meaningful index for dehydration tolerance (Anjum *et al.*, 2011). The RWC of flag leaf in studied varieties was measured at booting, anthesis and grain filling stages under water regimes (Table 2).

Table 2. Relative water content (%) of wheat varieties under water deficit condition

Wheat variety	Booting stage			Anthesis stage			Grain filling stage		
	control	water stress	% reduction	control	water stress	% reduction	control	water stress	% reduction
BARI Gom 25	94.41	83.17	11.97	89.51	76.72	14.29	78.81	60.71	22.97
BARI Gom 26	96.41	90.15	6.49	87.80	86.27	1.74	78.08	71.94	7.87
Sourav	96.93	88.08	9.13	84.71	82.79	2.26	76.62	68.75	10.27
CV(%	3.63,		1.52	6.67,		5.35	5.27,		7.32
$LSD_{(0.05)}$		4.83			9.13				8.19

The highest relative water content under irrigated condition was observed in Sourav (96.93%) at booting stage but during anthesis and grain filling stage BARI Gom 25 (89.51% and 78.81%) showed the highest value respectively. However BARI Gom 26 exhibits the highest relative water content at all the stages under water stress condition. The highest reduction occurred in BARI Gom 25 and the lowest in BARI Gom 26 at all observed stages under water deficit condition. These results are in accordance with the findings of Farooq *et al.*, 2009 and Jaleel *et al.*, 2008 that water deficit in different crop growth stages in different wheat varieties significantly decreased relative water contents.

Water uptake capacity (WUC) at booting, anthesis and grain filling stage in wheat varieties under variable water regimes varied significantly shown in table 3.

Table 3. Water uptake capacity of wheat varieties under water deficit condition

Wheat variety	Booting stage			Anthesis stage			Grain filling stage		
	control	water stress	% increase	control	water stress	% increase	control	water stress	% increase
BARI Gom 25	0.09	0.18	50.50	0.68	1.25	46.00	0.76	1.39	45.14
BARI Gom 26	0.08	0.11	22.28	0.65	0.80	18.75	0.69	0.90	23.27
Sourav	0.09	0.14	35.07	0.63	0.88	28.00	0.86	1.17	26.23
CV(%0 $LSD_{(0.05)}$	9.61,	0.04	21.96	10.95,	0.26	22.65	30.65,	0.48	24.62

The highest WUC was observed in BARI Gom 25 at booting (0.09 and 0.18) and anthesis (0.68 and 1.25) stages where it was lowest in BARI Gom 26 at booting (0.08 and 0.11) and anthesis (0.63 and 0.88) both under control and water stress condition, respectively. At grain filling stage Sourav (0.86) showed the highest value and BARI Gom 26 (0.69) exhibit the lowest value under irrigated condition where BARI Gom 25(1.39) obtained the highest value and it was lowest in BARI Gom 26(0.90) under water stress condition. The highest increases in water uptake capacity under water stress occurred in BARI Gom 25 and the lowest in BARI Gom 26 at all observed stages. The instantaneous water uptake capacity significantly increased under water stress as compared to the irrigated at studied stages. An increase WUC under water deficit condition was also reported by Abbad *et al.*, 2004. Similar results were also described by Choudhury (2009) and Mahmud (2012) that the tolerance varieties possessed the lowest WUC under water stress compared to other varieties.

Plants grow under high moisture regimes maintain a higher water retention capacity (WRC) which might be due to lower destruction of plant tissues by moisture deficit (Sangakkara *et al.*, 1996). WRC was decreased markedly in the studied varieties due to water stress at booting, anthesis and grain filling stages (Table 4).

Table 4. Water retention capacity of wheat varieties under water deficit condition

Wheat variety	Booting stage			Anthesis stage			Grain filling stage		
	control	water stress	% reduction	control	water stress	% reduction	control	water stress	% reduction
BARI Gom 25	4.15	3.50	15.68	4.87	3.58	26.50	4.74	3.31	30.17
BARI Gom 26	4.22	4.06	3.81	4.71	4.46	5.27	4.52	4.21	6.76
Sourav	4.61	4.32	6.43	4.87	4.42	9.14	4.76	4.18	12.30
CV(%) $LSD_{(0.05)}$	7.03,	0.47	5.54	13.86,	0.95	9.85	7.18,	0.50	5.97

The highest WRC was observed in Sourav (4.61, 4.87 and 4.76) where it was lowest in BARI Gom 25 (3.50, 3.58 and 3.31) at booting, anthesis and grain filling stages respectively under irrigated condition. On the other hand, Sourav showed the highest (4.32) at booting stage and BARI Gom 26 showed the highest (4.46 and 4.21) result at anthesis and grain filling stages where BARI Gom 25 showed the lowest (3.50, 3.58 and 3.31) result at booting, anthesis and grain filling stages under water stress condition. The highest reduction in WRC under water stress occurred in BARI Gom 25 and the lowest in BARI Gom 26 at all the studied stages. In the present study, BARI Gom 26 and Sourav showed the lowest reduction in WRC, and thus an indication of their tolerence to drought. Similar findings in WRC were reported by Choudhury (2009) in French bean and Martinez *et al.* (2007) in *Phaseolus vulgaris*.

Water saturation deficit (WSD) is the deviation of water content from the leaf compared to the saturation level of that leaf at a particular situation. A higher water saturation deficit indicates that the plants are subjected to a greater degree of water deficit. The present investigation showed a significant difference in WSD in wheat flag leaf at booting, anthesis and grain filling stage under variable water regimes. Water deficit significantly increased the WSD in wheat flag leaf irrespective of varieties. Regardless of the stages, the lowest WSD was obtained in control plants than stressed ones in all the varieties (Table 5).

Table 5. Water saturation deficit (%) of wheat varieties under water deficit condition

Wheat variety	Booting stage			Anthesis stage			Grain filling stage		
	control	water stress	% increase	control	water stress	% increase	control	water stress	% increase
BARI Gom 25	13.35	45.04	70.36	16.99	108.20	84.30	18.60	146.54a	87.31
BARI Gom 26	16.15	19.81	18.47	22.09	29.98	26.34	25.15	38.06c	33.92
Sourav	22.11	30.52	27.56	27.60	44.37	37.80	29.86	54.02b	44.72
CV(%)	9.65,		10.16	11.42,		15.21	9.63,		10.95
$LSD_{(0.05)}$		4.31			9.91			9.53	

The highest WSD was observed in Sourav (22.11, 27.60 and 29.86 %) where it was lowest in BARI Gom 25 (13.35, 16.99 and 18.60 %) at booting, anthesis and grain filling stages under irrigated condition, respectively. BARI Gom 25 showed the highest (45.04, 108.20 and 146.54 %) result and BARI Gom 26 showed the lowest (19.81, 29.98 and 38.06 %) result at booting, anthesis and grain filling stages under water stress condition. However, the highest increases in water saturation deficit under water stress occurred in BARI Gom 25 and the lowest in BARI Gom 26 at all the studied stages. The increasing trend of WSD under water deficit condition was also reported by Baque *et al.* (2006); Islam (2008); Mahmud (2012) and Choudhury (2009).

Conclusion

From the study, it can be concluded that water stress significantly influenced the physiological performance of wheat varieties. The performance of all varieties is better in all respect in irrigated as compared to water stress condition. The variety BARI Gom 26 is the best performing one under water deficit condition. The wheat var.

Sourav could take place after BARI Gom 26. BARI Gom 25 was affected more and shows the lowest result under water deficit condition.

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