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Effects of Water Stress on Morpho-Phenological Changes in Wheat Genotypes

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Keywords: wheat genotypes, morpho-phenological changes, water stress.

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EFFECTSOFWATERSTRESSONMORPHO-PHENOLOGICALCHANGESINWHEATGENOTYPES

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Md. Mahfuz Bazzaz [α], Abullah-Al-Mahmud [σ] & Md. Shawquat Ali Khan [ρ]

Abstract- The experiment was conducted with eleven wheat genotyps at the research field of Agronomy Department of the Bangabandhu Sheikh Mujibur Rahman Agricultural University from November 2011 to March 2012 to know the morpho-phenological changes in wheat and to identify water stress tolerant wheat genotypes. The experiment was carried out in a split-plot design comprising two water regimes in main plot and eleven wheat genotypes (BARI Wheat 25, BARI Wheat 26, Sourav, BAW 1157, BAW 1158, BAW 1159, BAW 1161, BAW 1165, BAW 1167, BAW 1169 and BAW 1170) were placed randomly in sub-plot with three replications. Water deficit condition caused an overall reduction in morphological and phenological attributes. The maximum reduction in plant height, peduncle length, flag leaf length and flag leaf area was by 25, 39, 27 and 57% in the genotypes BAW 1167, BAW 1167, BAW 1157 and BAW 1170, respectively under water deficit condition. The highest reduction in root volume and root dry weight was recorded in the genotype BAW 1167, while the lowest in BARI Wheat 26 and BAW 1169. The highest decrease in days to heading, days to physiological maturity and grain filling duration was noted in BAW 1167 and the lowest in BAW 1169, Sourav and BARI Wheat 26. The maximum number of days for grain filling was recorded in the genotype BARI Wheat 26, Sourav and BAW 1169, while the minimum in BAW 1167. From this experiment, it was concluded that the genotypes BARI Wheat 26 and BAW 1169 are water deficit tolerant and BAW 1167 is susceptible.

Keywords: wheat genotypes, morpho-phenological changes, water stress.

I. Introduction

Wheat, next to rice is the staple food of the people in Bangladesh grown over an area of 3.74 million hectare with an annual production of about 1 million metric tons with an average of 2.60 t ha^{-1} (Anonymous, 2011). This production is less than that of other countries because about one third of the total area under wheat in Bangladesh falls in the rainfed regions where water stress can limit plant growth and productivity either because of unexpected dry periods or due to very low or no rainfall (Khaliq *et al.,* 1999). Every year Bangladesh experiences a dry period of seven months from November to May when rainfall is normally low. During this period about 2.7 million hectares of land in Bangladesh is vulnerable to annual drought. Water having paramount importance in the plants, is essentially required at every stages of plant growth from seed germination to plant maturation. Crop plants require adequate water to grow at an optimum rate. Cultivated crops can't show its full genetic potential for yield due to certain environmental limitations especially water stress.

Water deficit inhibits cell enlargement more than cell division and reduces plant growth. Drought reduces leaf expansion (Alves and Setter, 2004), accelerates leaf senescence (de Souza *et al.,* 1997) and leads to death of leaf tissue. Water deficit may influence the phenology of the plant, for instance, it may push forward the flowering in wheat or delay the flowering in rice (Parchin *et al.,* 2011). Kiliç and Yağbasanlar (2010) observed that drought stress accelerated all the phenological growth stages, the normal growth and development periods, dry matter production and final yield.

Monsoon rains provide 80% annual precipitation in Bangladesh, and when this is reduced, water deficit becomes a significant problem. Most of the farmers in Bangladesh grow wheat with irrigation due to scarcity of water. Moreover, it is well known that the ground water table in Bangladesh is declining day by day. As a result wheat faces water deficit at later stages that reduces grain yield drastically. Research on plant response to water stress is becoming increasingly important, as most climate change scenarios suggest an increase in aridity in many areas of the globe (Petit *et al.,* 1999). Drought tolerant genotypes may only partially solve this problem. Little studies have been done in Bangladesh on these to identify wheat, which may act as supporting aspect for increasing wheat production in the country. Therefore, the present study was undertaken to know the morpho-phenological changes in wheat and to identify water stress tolerant wheat genotypes.

II. Materials and Methods

a) *Experimental Site, Soil and Climate*

The experiment was carried out at the research field of the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur from November, 2011 to March, 2012 on an upland soil. It is

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located at the center of Madhupur Tract (240 05′ North latitude and 90016′ East longitude) at an elevation of 8.4 m above the sea level. The soil of the experimental field belongs to Salna series of Shallow Red-Brown Terrace soil type (AEZ 28) with silty clay texture in surface and silty clay loam in sub-surface region of the soil (Brammer, 1971), (Shaheed, 1984). The experimental site is situated in the sub-tropical region characterized by heavy rainfall during the months from July to September and scanty or no rainfall in the rest of the year.

b) Test Crop

Eleven wheat genotypes including most of the popular varieties, some advanced lines and some lines from abroad collected from Wheat Research Centre of Bangladesh Agricultural Research Institute, Nashipur, Dinajpur, Bangladesh were used in the present study.

c) Land Preparation

The land was well prepared by repeated ploughing and cross-ploughing with a power tiller followed by laddering for breaking the clods, leveling the lands and collecting the stubbles. The individual plots were prepared by making ridges (8-10 cm high) around the each plot to restrict the lateral run off of fertilizer with irrigation water.

d) Experimental Design And Treatments

The experiment was carried out in a split-plot design comprising two water regimes in main plot and 11 wheat genotypes selected from previous experiment were placed randomly in sub-plot with three replications. The water regimes were (1) Non-stress (four irrigations were applied at crown root initiation, booting, anthesis and grain filling stages), and (2) Water stress (irrigation was stopped after crown root initiation stage i.e. 20 days after sowing and the crop was protected from rainfall by rainout shelter). The nine water deficit tolerance (BARI Gom 26, Sourav, BAW 1157, BAW 1158, BAW 1159, BAW 1161, BAW 1165, BAW 1169 and BAW 1170) and two susceptible (BARI Gom 25 and BAW 1167) wheat genotypes based on yield reduction were selected for the present experiment. The unit plot size was consisted of 6 rows each of 2.5 m long having a row to row distance of 20 cm.

e) Sowing of Seeds, Fertilizer Application and Intercultural Operation

Wheat seeds at the rate of 120 kg ha^{-1} were sown in line by hand on November 24, 2011. Seeds were placed continuously in lines by making narrow and shallow furrows with iron rod and covered with soil by hand. After sowing of seeds light irrigation was given to ensure uniform germination of seeds. Fertilizers were applied @ 100-60-40-20-1 kg ha^{-1} N-P_2O_5-K_2O-S in the form of urea, triple super phosphate, muriate of potash and gypsum, respectively. Two-third of urea and total amount of other fertilizers were applied during final land preparation. The rest amount of urea was top dressed at crown root initiation stage (20 days after sowing) followed by first irrigation. Intercultural operations were done uniformly in each plot to ensure normal growth of the crop. Weeding and mulching were done simultaneously in the experimental plot for two times, firstly at 15 days after sowing (DAS) and secondly, at 35 DAS. Thinning was also done at 14 DAS.

f) Data Collection

The data related to morphological and phenological parameters were recorded as described below.

g) Morphological Parameters

Plant height was recorded from the average of ten selected plants at maturity stage. Plant height (cm) was measured by a meter scale from soil surface to the tip of the spike excluding awns and averaged. Leaf area of the fully expanded flag leaf was collected from five selected plants at anthesis stage and measured in square centimeters using a calibrated automatic leaf area meter (Delta-T Devices Ltd., Burwell Cambs, UK). Then the measured data were expressed as means of three replications. The peduncle length of five main tillers was recorded by meter scale from the top joint up to the base of the spike in cm.

At harvest, three replicated plants per treatment were used to measure the root volume and root dry weight. The roots were collected from a depth of 0-20 cm and carefully cleaned with running tap water. The root volume was determined volumetrically with the help of a 100 ml measuring cylinder. The cylinder was filled up with 50 ml of tap water and then the total roots of a plant immersed into the water. The raised level of water due to immersion of the roots was recorded. The difference between final and initial volume was considered as root volume. Finally the root dry weight was measured after the samples were oven dried at 70oC for 72 hours.

h) Phenological Attributes

Days to heading was recorded by counting the number of days from the date of sowing till when 80% heads (eye estimation) were found completely visible in each row of the plot. Days to physiological maturity were calculated from sowing to the day when the peduncle and the spike on the tagged main stem became completely yellow. Grain filling duration was calculated by the number of days from heading to physiological maturity during the growing season for each genotype.

i) Statistical Analysis

The data were analyzed by MSTAT-C statistical package program. The difference between the treatments means were compared by least significant difference (LSD) test (Gomez and Gomez, 1983). Functional relationships among different parameters as affected by water deficit stress were established through correlation and regression analysis by using Excel program.

III. Results and Discussions

a) *Morphological Changes In Wheat Genotypes*

i. *Plant Height*

Different morphological characters such as plant height, flag leaf length and peduncle length were affected due to water deficit (Table 1). The plant height ranged from 76.31 to 90.27 cm and from 62.00 to 81.52 cm under control and water deficit, respectively. The tallest plant was obtained in the genotype BAW 1167 and the shortest in BAW 1158 under non-stress condition. The plant height was reduced under water deficit and the reduction was highest in BAW 1167 (25%) followed by BAW 1161 (22%) and BAW 1157 (21%) and the lowest reduction was recorded in the genotype Sourav (8%) followed by that in BAW 1159 (8%) and BARI Gom 26 (9%). The decrease in plant height might be due to decrease in relative turgidity and dehydration of protoplasm which is associated with a loss of turgor and reduced expansion of cell and cell division. Manivannan *et al.,* (2007) also mentioned that the reduction in plant height could be attributed to decline in the cell enlargement and more leaf senescence in the plant under water stress. The plant height in wheat reduced from 77 cm to 61.66 cm when irrigation was skipped at tillering stage of crop growth (Mushtaq *et al.,* 2011). These results are in agreement with the findings of Bayoumi *et al.,* (2008) who observed that drought caused reduction in plant height by 14.7 percent.

ii. *Flag Leaf Length*

The length of the flag leaf in different wheat genotypes was significantly affected by variable water regimes. The flag leaf length ranged from 22.00 to 28.28 cm and from 15.99 to 20.65 cm under control and water stress condition, respectively (Table 1). The maximum flag leaf length was recorded in the genotype BAW 1167 and the minimum in BAW 1158 in irrigated condition, while the maximum and minimum flag leaf length was recorded in the genotype BAW 1161 and BAW 1165, respectively under water stress condition. The highest reduction in flag leaf length was observed in the genotype BAW 1167 (39%), while the least reduction was obtained in the genotype BAW 1158 (11%) due to water stress. These results are in agreement with the findings of Sangtarash (2010) who found that flag leaf length was significantly affected by water stress in wheat.

iii. *Peduncle Length*

The peduncle length was also significantly affected by variable water regimes. The peduncle length ranged from 14.98 to 21.15 cm and from 12.17 to 13.35 cm under irrigated and water stress condition, respectively (Table 1). However, the longest peduncle was measured in the genotype BAW 1159 and the shortest in BAW 1161 under non-stress condition, while under water stress condition the longest peduncle was observed in BAW 1170 and the shortest in BAW 1167. The highest reduction in peduncle length was found in the genotype BAW 1157 (27%), while the minimum reduction was obtained in the genotype BARI Gom 25 (13%) due to water stress. These results are in harmony with the findings of Sangtarash (2010) who found that water stress in wheat significantly reduced the peduncle length. Kazmi *et al.,* (2003) reported similar result that water stress imposed to wheat significantly reduced the peduncle length (36%). The highest (30.04 cm) and the lowest (17.04 cm) peduncle length produced in well watered and severe water stress respectively were reported by Moghaddam *et al.,* (2012).

Table 1 : Plant height, flag leaf length and peduncle length in wheat genotypes under water stress condition

Genotypes	Plant height (cm)		% decrease	Flag leaf Length (cm)		% decrease	Peduncle length(cm)		% decrease
	Non-stress	Stress		Non-stress	Stress		Non-stress	Stress	
BARI Gom 25	87.60	71.37	19	25.43	17.9	30	17.75	15.38	13
BARI Gom 26	87.63	79.40	9	26.95	19.32	28	18.09	15.61	14
Sourav	88.27	81.52	8	25.25	18.57	26	20.91	17.34	17
BAW 1157	78.35	62.00	21	23.73	17.22	27	17.61	12.89	27
BAW 1158	76.31	64.73	15	22.00	19.62	11	18.39	15.61	15
BAW 1159	82.67	76.03	8	24.75	20.65	17	21.15	17.21	19
BAW 1161	80.45	63.00	22	24.33	15.99	34	14.98	12.31	18
BAW 1165	79.65	69.13	13	23.83	18.94	21	19.39	16.17	17
BAW 1167	90.27	68.07	25	28.28	17.35	39	16.25	12.17	25

BAW 1169	89.93	77.10	14	22.93	18.5	19	18.19	15.57	14
BAW 1170	77.21	68.40	11	25.7	17.22	33	20.33	17.38	15
LSD (5%)	3.94			1.71			1.31		
CV (%)	4.34			6.78			6.67		

iv. *Flag Leaf Area*

The flag leaf area in wheat varied markedly among genotypes under variable water regimes (Fig. 1). Under control condition, the maximum flag leaf area was exhibited by the genotype BARI Gom 25 (46.87 cm^2) and the lowest in BAW 1169 (28.61 cm^2). But, the flag leaf area drastically reduced in all genotypes due to water stress stress which ranged from 53 to 30 cm^2. However, the genotype BAW 1167 exhibited the maximum reduction in flag leaf area which was followed by the genotypes BARI Gom 25 and BAW 1157 and the minimum reduction was in BAW 1158 which was followed by those in BARI Gom 26 and BAW 1169. These results are in harmony with those reported by El-Danasory (2005), Kazmi *et al.,* (2003) and Khakwani, *et al.,* (2012) who concluded that the flag leaf area was significantly reduced by water stress. Alves and Setter (2004) showed that both cell expansion and production of cells contributed to a loss in leaf area depending on the developmental stage at which the leaf was stressed.

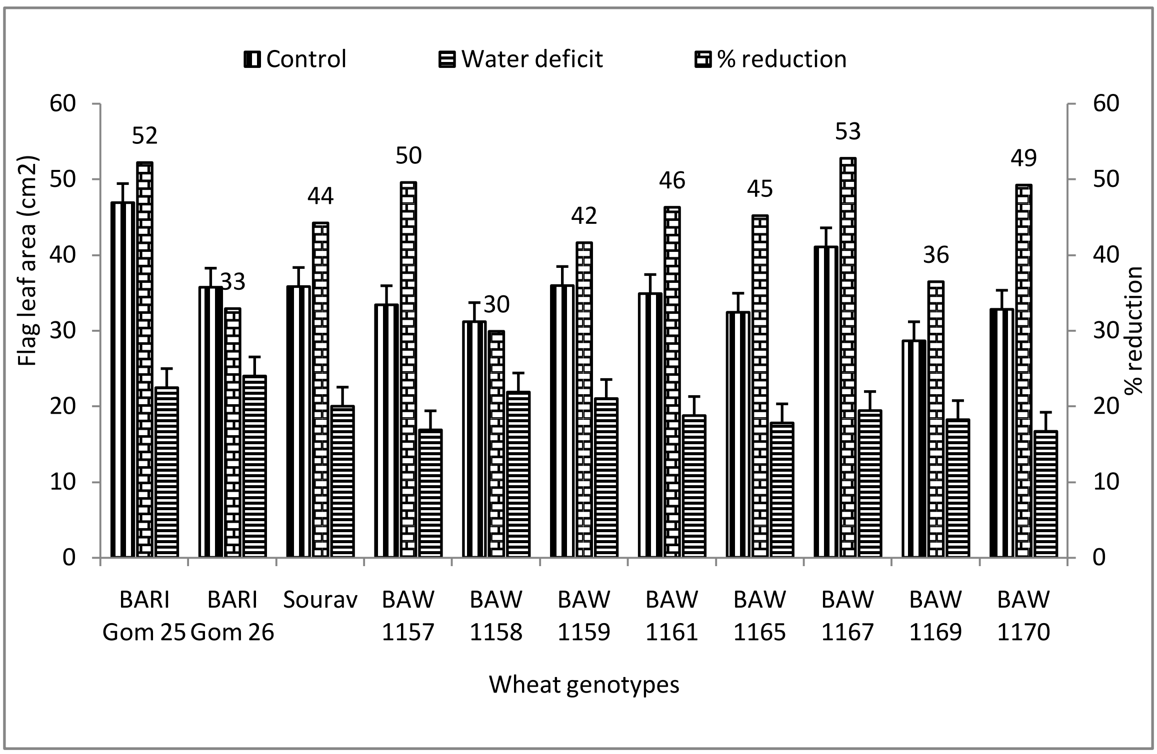

Figure 1 : Flag leaf area in wheat genotypes under non-stress and water stress conditions. Vertical bars indicate LSD at 5% level of significance

v. *Root Volume and Dry Weight*

The present study showed a significant difference in root dry weight and root volume among the genotypes under water stress condition (Fig. 2 and 3). The root volume ranged from 0.46 to 0.61 mm and from 0.37 to 0.52 mm $plant^{-1}$ under non-stress and water stress condition, respectively. The highest root volume was obtained in the genotype BARI Gom 26 (0.52 mm $plant^{-1}$), while the lowest in BAW 1167 (0.37 mm $plant^{-1}$). However, the highest reduction in root volume was recorded in genotype BAW 1167 (33.93%), whereas the lowest in BARI Gom 26 (7.14%). The root dry weight in 11 wheat genotypes followed the similar trend observed in root volume, and varied from 2.27 to 3.10 g plant-1 and from 1.81 to 2.81 g $plant^{-1}$ under non-stress and water stress conditions, respectively. The higher root dry weight was recorded in the genotype BAW 1159 (2.81 g $plant^{-1}$) and the lowest in BAW 1167 (1.81 g $plant^{-1}$). Similar results were also reported by Gesimba *et al.,* (2004) who found that the drought tolerant genotypes had significantly more roots in the crown region, while the susceptible genotypes had fewer roots. Reduction in root volume under osmotic stress originates not only from growth inhibition but also from a loss of turgidity, as reported in wheat (Benlaribi *et al.,* 1990; Ali Dib and Monneveux, 1992).

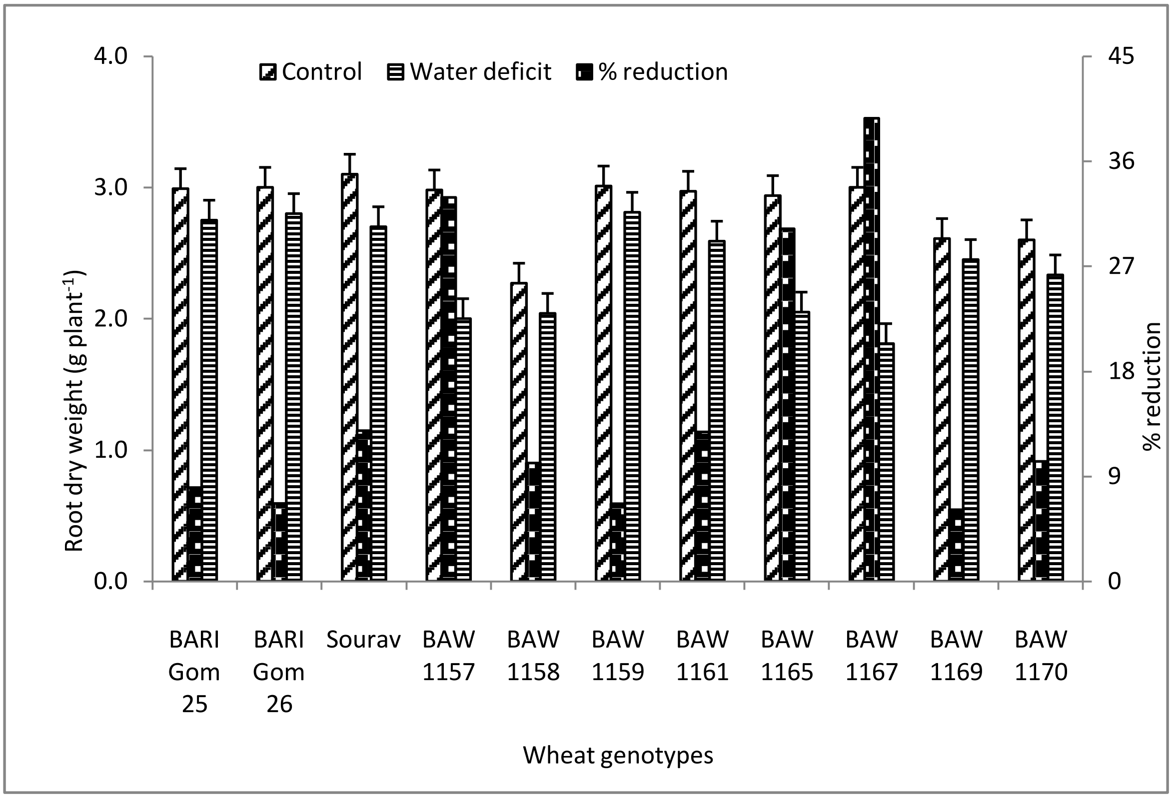

Figure 2 : Root dry weight in wheat genotypes under non-stress and water stress conditions. Vertical bars indicate LSD at 5% level of significance

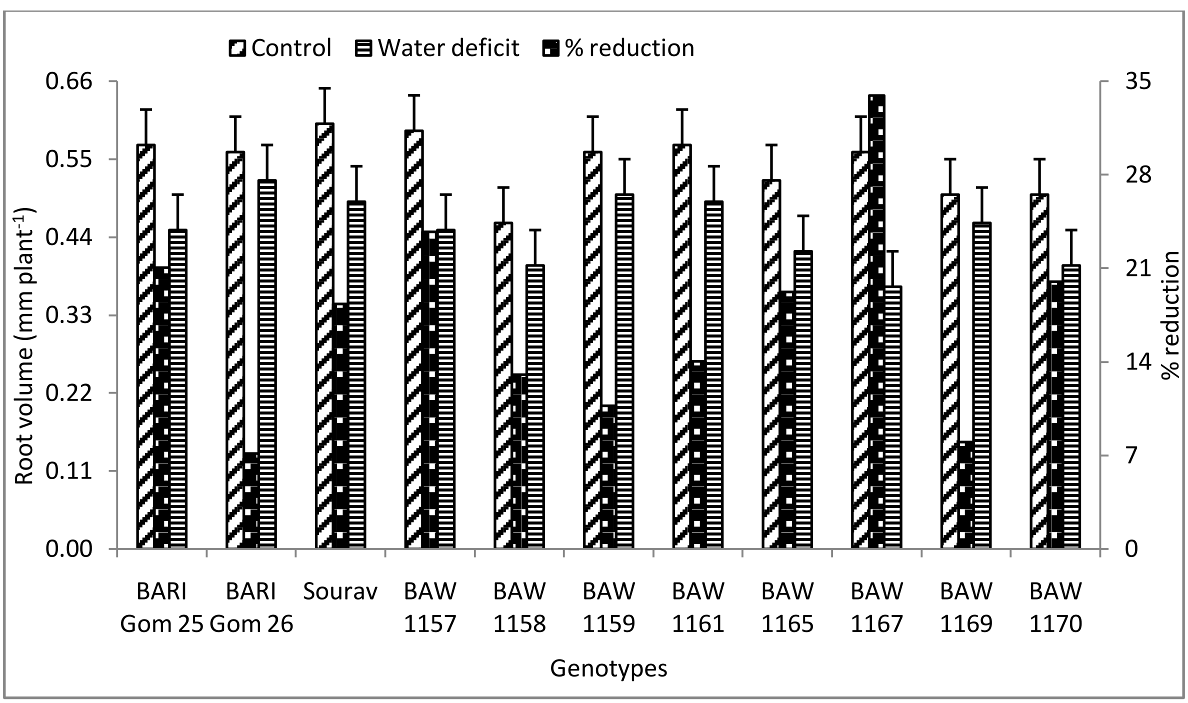

Figure 3 : Root volume in wheat genotypes under non-stress and water stress conditions. Vertical bars indicate LSD at 5% level of significance

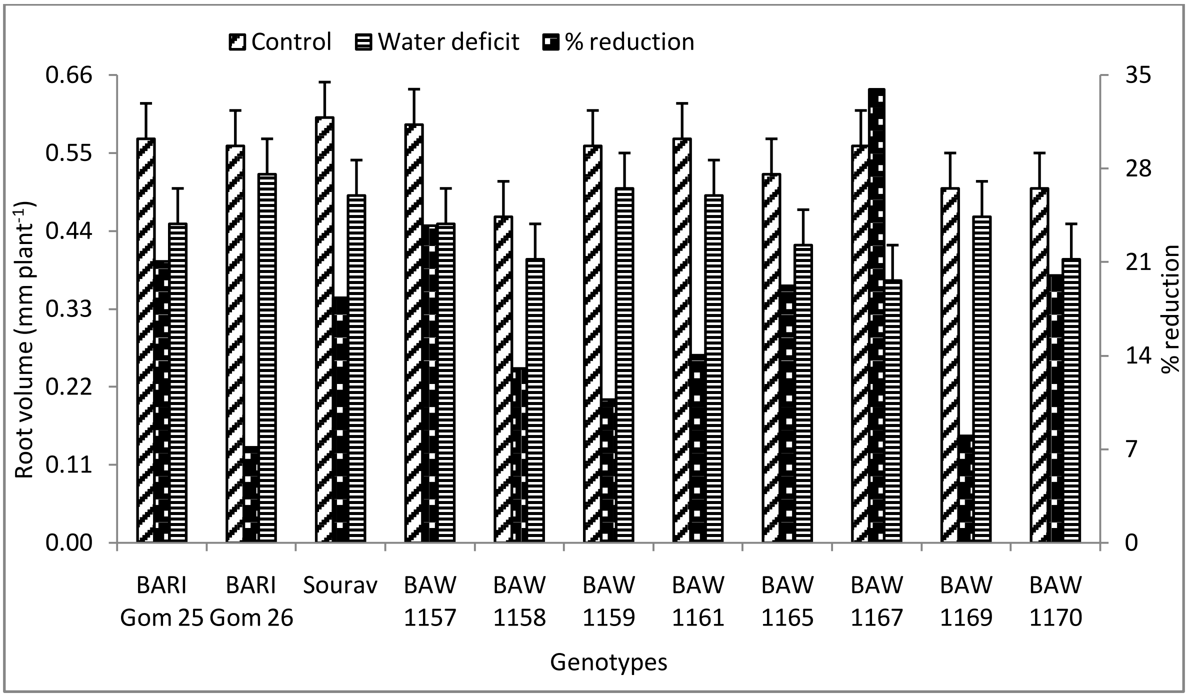

Figure 3 : Root volume in wheat genotypes under non-stress and water stress conditions. Vertical bars indicate LSD at 5% level of significance

b) *Phenological Parameters*

i. *Days to Heading, Physiological Maturity and Grain Filling Duration*

The phenological traits such as Days to heading, days to physiological maturity and days to grain filling duration were reduced significantly under water stress condition (Table 2). The number of days to heading ranged from 66 to 70 and from 59 to 69 under non-stress and water stress conditions, respectively. But the heading was 7 days earlier in the genotypes BAW 1158 and BAW 1170, whereas 1 to 3 days earlier in the genotypes BAW 1169, BARI Gom 26 and Sourav over control. The physiological maturity ranged from 106 to 111 and from 91 to 106 days under water stress and water stress condition, respectively. However, the higher earliness for physiological maturity was observed in the genotype BAW 1167 (18 days), whereas only 4 to 6 days earlier for physiological maturity was observed in BAW 1169, BARI Gom 26 and Sourav as compared to control. The most important phenological trait, days to grain filling, varied significantly and ranged from 37 to 41 and from 28 to 38 days under non-stress and water stress conditions, respectively. The maximum number of days for grain filling was recorded in the genotype BARI Gom 26 (38 days), while the minimum period for grain filling was observed in the genotype BAW 1167 (28 days). Similar results were also reported by various researchers that drought reduced the number of days to heading (Kiliç and Yağbasanlar, 2010; Bayoumi et al., 2008; Sial *et al.,* 2009; Khakwani *et al.,* 2012; Kılıç *et al.,* 1999), days to maturity (Kiliç and Yağbasanlar, 2010; Saleem *et al.,* 2007) and grain filling period (Kiliç and Yağbasanlar, 2010; Sial *et al.,* 2009). Drought decreases the seed-filling duration, leading to smaller seed size (Frederick *et al.,* 1991; de Souza *et al.,* 1997).

Table 2 : Days to heading, days to physiological maturity and grain filling duration in wheat genotypes under non-stress and water stress conditions

Genotypes	Days to heading			Days to physiological maturity			Grain filling duration		
	Non-stress	Water stress	Earliness over control	Non-stress	Water stress	Earliness over control	Non-stress	Water stress	Earliness over control
BARI Gom 25	69	63	6	109	94	15	40	31	9
BARI Gom 26	69	66	3	109	104	5	40	38	2

Sourav	70	67	3	110	104	6	40	37	3
BAW 1157	69	63	6	106	91	15	37	28	9
BAW 1158	66	59	7	106	92	14	40	33	7
BAW 1159	69	64	5	109	99	10	40	35	5
BAW 1161	69	63	6	109	94	15	40	31	9
BAW 1165	70	65	5	109	98	11	39	33	6
BAW 1167	70	65	5	111	93	18	41	28	13
BAW 1169	70	69	1	110	106	4	40	37	3
BAW 1170	68	61	7	106	93	13	38	32	6
LSD (5%)		2.20			1.54			2.22	
CV (%)		2.82			1.28			5.25	

ii. *Correlation Between Yield and Phenological Traits*

The correlation between yield and phenological traits such as days to heading, days to physiological maturity and days to grain filling showed a marked variation under water stress as shown in Table 3. A significant positive correlation was found between grain yield under water stress condition and days to heading ($P<0.05$), days to physiological maturity ($P<0.01$) as well as days to grain filling period ($P<0.01$). But under non-stress condition, no significant correlation was found between grain yield and above traits. Moreover, among the phenological traits, the days to physiological maturity showed very strong and positive correlation with grain yield which was followed by that in days to grain filling period and days to heading. The relationship between grain yield and days to heading indicates that the yield can vary by 71% due to the variation in days to heading. On the other hand, the relationship between grain yield and days to physiological maturity as well as days to grain filling suggests that the yield can vary by 89% and 86% due to the variation in days to physiological maturity and days to grain filling periods, respectively. The days to heading also showed a significant positive correlation with days to physiological maturity ($P<0.01$) and days to grain filling period ($P<0.05$). Similarly, the days to physiological maturity showed a significant positive correlation with days to grain filling period (($P<0.01$). A positive and significant correlation was observed between grain yield and grain filling period, while a negative and significant correlation was observed between grain yield and number of days to heading as reported by Kiliç and Yağbasanlar (2010). Likewise, the negative correlation between yield under stress and flow¬ering date has frequently been found (Dodig *et al.,* 2010).

Table 3 : Correlation between grain yield and days to heading, days to physiological maturity and grain filling duration in wheat under non-stress and water stress conditions

Trais	Yp	Ys	Heading (days)	Physiological maturity (days)	Grain filling period (days)
Yp	1.00				
Ys	0.23	1.00			
Heading (days)	0.29	0.714*	1.00		
Physiological maturity (days)	0.24	0.893**	0.84**	1.00	
Grain filling period (days)	0.17	0.862**	0.61*	0.95**	1.00

p < 0.05, p**< 0.01, Yp= grain yield under control, and Ys= grain yield under water deficit*

IV. Conclusion

The results of this study indicated that all the parameters in morpho-phenology of eleven wheat genotypes reduced remarkably under water stress condition. The highest reduction in plant height, peduncle length, flag leaf length and flag leaf area was by 25% in BAW 1167, 39% in BAW 1167, 27% in BAW 1157 and 57% in BAW 1170 and the lowest reduction was by 8% in Sourav, respectively under water stress condition. The highest reduction in root volume and root dry weight under water deficit was recorded in the genotype BAW 1167, while the lowest in BARI Gom 26 and BAW 1169. The maximum number of days for grain filling under water stress condition was recorded in the genotype BARI Gom 26 which was at par with Sourav and BAW 1169, while the minimum in the genotype BAW 1167. From this experiment, it was concluded that the genotypes BARI Gom 26 and BAW 1169 are water stress tolerant and BAW 1167 is susceptible.

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