South Asian Journal of BIOLOGICAL RESEARCH

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Sheikh Sohorab Ali, Sripati Sikder, Subrota Kumer Pramanik
**Corresponding author E-mail: srisikder@gmail.com*

To cite the article: Sheikh Sohorab Ali, Sripati Sikder, Subrota Kumer Pramanik (2018). Effect of non-irrigated water stress on phenology and yield performance of wheat genotypes (*Triticum aestivum* L.), *South Asian Journal of Biological Research*, 1(1): 42-52.

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EFFECT OF NON-IRRIGATED WATER STRESS ON PHENOLOGY AND YIELD PERFORMANCE OF WHEAT GENOTYPES (*Triticum aestivum* L.)

***Sheikh Sohorab Ali*[1]*, Sripati Sikder*[2]*, Subrota Kumer Pramanik*[3]**
**Corresponding author E-mail: srisikder@gmail.com*

ARTICLE INFO
Article Type: Research
Received: 10, Sep. 2018.
Accepted: 07, Oct. 2018.
Published: 14, Oct. 2018.

Keywords:
Wheat, Water deficit stress, Phenology, Yield, Stress tolerance

ABSTRACT

To study phenology and yield performance of wheat genotypes under well water and water stress condition the present experiment was conducted in a split-plot design with three replications. Under water stress condition, all the wheat genotypes required more or less short time to attain certain phonological stages compared to well water condition. Water stress leads to a noticeable decrease in different yield components of wheat genotypes. Under well water condition, the highest above ground biological yield and grain yield were found in BAW 1177 (9.43 t ha^{-1} and 4.20 t ha^{-1}, respectively), whereas the lowest value in that cases were observed in ESWYT 29 (7.81 t ha^{-1} and 3.20 t ha^{-1}, respectively). Under water stress condition, more reduction in above ground biological yield and grain yield was observed in sensitive genotype ESWYT 29, while less reduction was observed in BAW 1177. Water stress increased the harvest index in BARI Gom 29 but decreased in BARI Gom 28, BAW 1177 and ESWYT 29 compared to well water condition. The order of stress tolerance based on above ground biological yield was BAW 1177 > BARI Gom 28 > BARI Gom 29 > ESWYT 29 and based on grain yield was BAW 1177 > BARI Gom 29 > BARI Gom 28 > ESWYT 29.

1. Introduction

Wheat (*Triticum aestivum* L.) is the most important stable diet for more than one third of the world population and contributes more calories and protein to the world diet than any other cereal crops (Abd-El-Haleem*et al.* 2009). In Bangladesh, wheat is the second important cereal crop next to rice grown over an area of 0.44 million hectares with an annual production of about 1.31 million metric tons with an average production of 3.03 t ha^{-1} (BBS 2017). Wheat has now become an indispensable food item of the people of Bangladesh and it continues to fill the food gap caused by possible failure of rice crop (Karim *et al.* 2010). Though wheat is an important cereal crop in Bangladesh its average yield is low compared to that of the advanced countries of the world. It is due to about one third of the total area under wheat in

[1] Sheikh Sohorab Ali, Former MS Student, Department of Crop Physiology and Ecology, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh.
[2] Sripati Sikder, Professor, Department of Crop Physiology and Ecology, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh.
[3] Subrota Kumer Pramanik, Former MS Student, Department of Crop Physiology and Ecology, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh.

Bangladesh falls in the rainfed regions where water stress limit plant growth and productivity (Khaliq *et al.* 1999). Moreover, it is well known that the ground water table in Bangladesh is declining day by day. Global climate change is making drought stress as a critical factor for plant growth and productivity. Drought adversely affects plant growth and development, seed germination (Dash and Panda 2001) and seedling growth (Ashraf *et al.* 2002). Kilic and Yagbasanlar (2010) observed that drought stress accelerated all the phenological growth stages, the normal growth and development periods, dry matter production and final yield. In this situation, drought tolerant genotypes may only partially solve this problem. Therefore, identification of wheat genotypes through high relative yield suitable for water stress condition would be an important step for achieving the high potential of yield. To screen wheat genotypes with high yield potential under water stress condition, the present study was undertaken to evaluate the phenology and variation in yield and yield components and to screen out the relative drought tolerant wheat genotype(s) under non-irrigated water stress condition.

2. Materials and methods

The experiment was carried out at the research field of Crop Physiology and Ecology Department, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh during November 2015 to April 2016 located at 25º39′ N latitude and 88º41′ E longitude with an elevation of 37.58 meters above the sea level. The experimental field was under the Agro-ecological zone (AEZ-1) of Old Himalayan Piedmont Plain. The experiment was conducted in a split- plot design with three replications. The unit plot size was 3.0 m × 2.0 m. Two growing conditions: A) well water (Irrigation was applied at crown root initiation, anthesis and grain filling stages) and B) water stress (No irrigation was applied) were placed as main plot treatments, whereas four wheat genotypes (BARI Gom 28, BARI Gom 29, BAW 1177 and ESWYT 29) were placed randomly as sub plot treatments. Seeds of wheat genotypes were sown at the rate of 120 kg ha^{-1} in rows of 20 cm apart. Slight irrigation was given for uniform germination after sowing and recommended production technology of wheat was followed.

2.1 Soil moisture determination

The soil samples were collected by an augur from each plot at a depth of 15 cm and were taken in air tight containers. The samples were weighed, and then they were dried in an oven at 70°C for 72 hours. The samples were then taken out from oven and weighed again, and the loss in weight (Wt.) is the amount of soil moisture.

Soil moisture content (%) = {(Wt. of the moist sample - Wt. of oven dry sample) / Wt. of oven dry sample} × 100

2.2 Phenology

Phenological stages viz. seedling emergence, tillering, anthesis, physiological maturity and harvest maturity were recorded in days when 50% plants of each plot reached a definite stage as the representative of that stage.

2.3 Yield and yield components

Different traits such as number of effective tillers $plant^{-1}$, number of spikes m^{-2}, spike length, grains per spike, thousand grain weight, above ground biological yield and grain yield of wheat genotypes were taken and recorded properly. Grain yield was adjusted to 12% moisture content. Harvest index was calculated using the following formula-

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

2.4 Relative performance

The relative performance was calculated using the following formula as described by Asana and William (1965).

$$\text{Relative performance (\%)} = \frac{\text{Variable measured under stress condition}}{\text{Variable measured under normal condition}} \times 100$$

2.5 Stress tolerance index

Stress tolerance index was calculated as Goudarzi and Pakniyat (2008) using the following formula-

$$\text{Stress tolerance index} = \frac{\text{Variable measured under stress condition}}{\text{Variable measured under normal condition}}$$

2.6 Statistical analysis

The collected data were analyzed by partitioning the total variance using the STATA program (small STATA 12.0), and the treatment means were compared using Tukey's test.

3. Results and Discussions

3.1 Soil moisture content

Figure 1 shows that soil moisture content at a 0-15cm depth of well water and water stressed plots at different days after sowing. It indicates that well water plot maintained higher soil moisture (9.35%, 11.32% and 10.62%) than that of water stressed plot (6.37%, 5.74% and 5.35%) at 70, 90 and 110 days after sowing, respectively. This figure also presents that with the advancement of time after sowing, soil moisture of water stressed plot was reduced gradually. The variation between soil moisture at well water and water stress conditions was much more at 90 days after sowing (5.58%) than that of 70 and 110 days after sowing (2.98% and 5.27%, respectively). At 70 and 110 days after sowing the difference between the moisture contents at both well water and water stress condition was less. It might be due to at early growth stage of wheat there was precipitation, and the rate of evapotranspiration was less due to less sunlight and temperature. But with the advancement of time, there was no precipitation, and the temperature was raised due to more sunlight resulted in more loss of water from the soil through evapotranspiration. It also might be due to at early growth stage the plants uptake comparatively less water than later stages. The findings of the present study are in agreement with the Payero *et al.* (2009) and Rana *et al.* (2017).

3.2 Phenology

Phenology of four wheat genotypes at different growing conditions is shown in Table 1. Results reveal that the phenology was significantly influenced by the interaction effect of water regimes and wheat genotypes except days required to attain booting and anthesis. For each genotype, a definite days was required to attain certain phenological stages of growth. At well water condition, BARI Gom 28, BARI Gom 29 and BAW 1177 required each of 6 days for seedling emergence, whereas ESWYT 29 required 5 days for seedling emergence. At water stress condition, BARI Gom 29 and ESWYT 29 required 1 day more, but BARI Gom 28 and BAW 1177 required same days for seedling emergence compared to well water condition.

Under well water condition, genotype BARI Gom 29 required 27 days, whereas BARI Gom 28, BAW 1177 and ESWYT 29 required 26 days to attain tillering stage. Under water stress condition, BARI Gom 29 and ESWYT 29 attained tillering stage at 1 day earlier, and BAW 1177 attained at 2 days earlier, whereas BARI Gom 28 required an equal number of days to attain at the respective stage. Under well water condition, genotypes BARI Gom 28 and BARI Gom 29 required 76 days for anthesis, 101 days for physiological maturity and 113 days for harvest maturity, whereas these growth durations were 80, 106 and 115 days in BAW 1177 and 84, 112 and 116 in ESWYT 29.

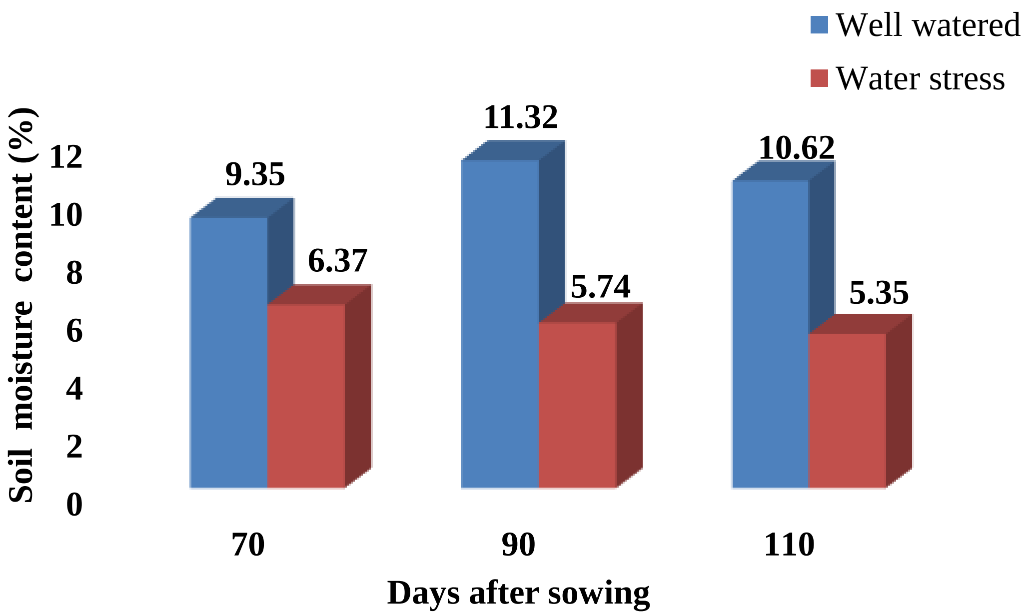

Figure 1: Soil moisture content (0-15 cm depth) at different days after sowing as influenced by water regimes.

Table 1. Phenology (days after sowing) of four wheat genotypes under well water and water stress conditions

Wheat genotypes	Water levels	Seedling emergence	Tillering	Anthesis	Physiological maturity	Harvest maturity
BARI Gom 28	Well water	6ab	26b	76	101b	113bc
	Water stress	6ab	26b	75	100b	112c
BARI Gom 29	Well water	6ab	27a	76	101b	113bc
	Water stress	7a	26b	74	101b	113bc
BAW 1177	Well water	6ab	26b	80	106a	115a
	Water stress	6ab	24d	79	104a	113bc
ESWYT 29	Well water	5b	26b	84	112a	116a
	Water stress	6ab	25c	83	110a	114b
Level of significance		*	*	NS	*	**
CV (%)		1.67	2.08	1.74	2.52	1.51

In a column, means followed by the same letter(s) did not differ significantly at the 5% level by Tukey.

Under water stress condition, all the genotypes required comparatively shorter days to attain reproductive stages (anthesis to harvest maturity) compared to well water condition except BARI Gom 29 at physiological maturity and harvest maturity. From the result, it was found that ESWYT 29 required the highest number of days to attain harvest maturity under well water condition followed by BAW 1177, whereas BARI Gom 28 and BARI Gom 29 required comparatively lowest number of days to attain harvest maturity. Under water stress condition, BARI Gom 28 attained harvest maturity at 1 day earlier, whereas BAW 1177 and ESWYT 29 attained 2 days more prior and BARI Gom 29 required equal number of days to attain harvest maturity stage compared to well water condition.

In principle, the length of growing period and phenological development of crops can affect the yield either by consuming more resources or by decreasing the environmental tensions or by reducing the length of the periods (Attarbashi *et al*. 2002). Similar results were also reported by Khakwani *et al.* (2012) and Kilic and Yagbasanlar (2010).

3.3 Number of effective tillers plant^{-1}

The combined effect of water regimes and wheat genotypes on number of effective tillers per plant was significant (P<0.05) (Table 2). Under well water condition, the highest number of effective tillers per plant was found in BAW 1177 (5.44) which was followed by BARI Gom 28 (5.25), whereas BARI Gom 29 and ESWYT 29 produced similar number of effective tillers per plant (4.66). The effect of water stress was found to reduce number of effective tillers per plant in all wheat genotypes. However, the degree of reduction was different in different genotypes. Under water stress condition, more reduction in number of grains per spike was observed in genotype BARI Gom 28 (30.29%) followed by ESWYT 29 (29.18%) compared to other two genotypes BARI Gom 29 (10.73%) and BAW 1177 (15.99%). In case of number of effective tillers per plant, the maximum relative performance was observed in genotype BAW 1177 (84.00%), whereas minimum relative performance was observed in genotype ESWYT 29 (70.81%). In water stress, plant suffers from physical drought and consequently the reduction in number of effective tillers per plant was observed. Similar response of different wheat genotypes to different moisture levels was also found by Rashid *et al*. (2003) and Rafiq *et al*. (2005).

3.4 Number of spikes m^{-2}

Table 3 shows that the interaction effect of two water regimes and four wheat genotypes on number of spikes per square metre was significant (P<0.01). Under well water condition, the highest number of spikes per square metre was found in BAW 1177 (336) which were followed by BARI Gom 28 (312) and BARI Gom 29 (297), whereas the lowest number of spikes per square metre was observed in ESWYT 29 (278). In all wheat genotypes, number of spikes per square metre was vigorously affected due to the effect of non-irrigated water stress. However, the degree of reduction was not similar in all genotypes.

Under water stress condition, maximum reduction in number of spikes per square metre (19.78%) was observed in sensitive genotype ESWYT 29, whereas the minimum reduction in number of spikes per square metre (5.88%) was found in BAW 1177. In term of relative performance, highest performance was found in BAW 1177 (94.11%) followed by BARI Gom 28 (84.93%) and BARI Gom 29 (89.89%), whereas lowest performance (88.06%) was found in ESWYT 29. These results are in a line with the findings of Afzal *et al.* (2006) and Mushtaq *et al*. (2011)

3.5 Spike length

Spike length was significantly influenced by the combined effect of water regimes and wheat genotypes (P<0.05) (Table 5). At well water condition, longest spike was produced by BAW 1177 (11.02 cm). The second longest spike was produced by BARI Gom 29 (10.97 cm) which was statistically at par with BARI Gom 28 (10.47 cm), whereas genotype ESWYT 29 produced significantly the shortest spike (10.17 cm). Due to water stress spike length was significantly reduced in all wheat genotypes but the degree of reduction was different for different wheat genotypes. More reduction in spike length (10.02%) was observed in genotype ESWYT 29 compared to others, where BARI Gom 29 showed 9.21% reduction and BARI Gom 28 and BAW 1177 showed more or less similar reduction (4.01% and 4.08%, respectively) in spike length. In case of relative performance, highest performance was found in BARI Gom 28 (95.99%) followed by BAW 1177 (95.91%), whereas 90.79% and 89.97% relative performance was found in BARI Gom 29 and ESWYT 29, respectively. Similar results were also reported by Baque (2003).

3.6 Number of grains spike^{-1}

The interaction effect of water regimes and wheat genotypes on number of grains per spike was significant (Table 6). Under well water condition, the highest number of grains per spike was found in BAW 1177 (49.26) which was followed by BARI Gom 28 (47.51) and BARI Gom 29 (47.15), whereas the lowest number of grains per spike was found in ESWYT 29 (44.75). The effect of water stress was found to reduce number of grains per spike in all wheat genotypes. But the degree of reduction was different in different genotypes. Under water stress condition, more reduction in number of grains per spike was observed in sensitive genotype ESWYT 29 (12.67%) followed by BARI Gom 29 (12.26%) compared to two tolerant genotypes BARI Gom 28 (4.71%) and BAW 1177 (4.79%). In case of grain per spike the order of relative performance was BARI Gom 28 > BAW 1177 > BARI Gom 29 > ESWYT 29.

Water stress limits seed numbers by either influencing the amount of dry matter produced by the time of flowering or by directly influencing pollen or ovule function, which leads to decreased seed set (Prasad *et al.* 2008). Similar response of different wheat genotypes to different moisture levels was found by Rana *et al.* (2017).

Table 2. Different yield components of four wheat genotypes under well water and water stress conditions

Wheat genotypes	Water Levels	Effective tillers plant^{-1}		Spike m^{-2}		Spike length		Grain spike^{-1}	
		Number	RP (%)	Number	RP (%)	cm	RP (%)	Number	RP (%)
BARI Gom 28	Well water	5.25a	79.23	312a	84.93	10.47bcd	95.99	47.51ab	95.28
	Water stress	3.66cd		265b		10.05cd		45.27c	
BARI Gom 29	Well water	4.66ab	78.54	297a	89.89	10.97ab	90.79	47.15ab	87.74
	Water stress	4.16bcd		267b		9.96d		41.37de	
BAW 1177	Well water	5.44a	84.00	357a	94.11	11.02a	95.91	49.26a	95.20
	Water stress	4.57abc		336a		10.57abc		46.90ab	
ESWYT 29	Well water	4.66ab	70.81	278b	80.21	10.17cd	89.97	44.75cd	87.32
	Water stress	3.3d		223c		9.15e		39.08e	
Level of significance		*		**		*		*	
CV (%)		7.25		1.58		3.86		2.92	

In a column, means followed by the same letter(s) did not differ significantly at the 5% level by Tukey.

RP = Relative performance

3.7 Thousand Grain weight

The combined effect of water regimes and wheat genotypes on 1000-grain weight was not found to be significant but 1000-grain weight was significantly influenced by the main effect in the present study (Table 8). Water stress reduced the 1000-grain weight of all the wheat genotypes (40.70 g to 45.40 g) compared to well water condition (42.90 g to 47.10 g). At both well water and water stress conditions, wheat genotype BAW 1177 produced the highest 1000-grain weight (47.10g and 45.40 g, respectively), whereas ESWYT 29 produced the lowest 1000-grain weight (40.70 g and 42.90 g, respectively). In term of relative performance, BAW 1177 was found showing better relative performance (96.39%) compared to other three genotypes, of which BARI Gom 29 was found performing lowest relative performance (93.39%) in 1000-grain weight.

The 1000-grain weight of wheat genotypes was reduced significantly under water stress condition, and this reduction may be due to the reduction in grain size per spike which favours the reduced grain weight. This result is in a line with the results observed by Sikder *et al.* (2011).

3.8 Above ground biological yield

Above ground biological yield was influenced significantly (P<0.05) by the combined effect of water regimes and wheat genotypes (Table 7). Under well water condition, the highest above ground biological yield was found in BAW 1177 (9.43 t ha^{-1}) which was followed by BARI Gom 28 (8.81 t ha^{-1}) and BARI Gom 29 (8.93 t ha^{-1}), whereas the lowest above ground biological yield was observed in ESWYT 29 (7.81 t ha^{-1}). Due to water stress above ground biological yield was reduced in all wheat genotypes. But the degree of reduction was different in different genotypes. Under water stress condition, more reduction in above ground biological yield was observed in sensitive genotype (23.81% in ESWYT 29) compared to three tolerant genotypes (14.30% in BARI Gom 28, 20.26% in BARI Gom 29 and 13.46% in BAW 1177). In the case of relative performance, the maximum value was observed in BAW 1177 (86.53%) followed by BARI Gom 28 (85.69%), whereas the minimum value was observed in ESWYT 29 (76.18%). The moderate value of relative performance was found in BARI Gom 29 (79.73%). Similar results were also observed by Almeselmani *et al*. (2011)

3.9 Grain yield

The interaction effect of water regimes and wheat genotypes on grain yield was found to be significant (P<0.05) in the present study (Table 7). Under well water condition, the highest grain yield was found in BAW 1177 (4.20 t ha^{-1}) which was followed by BARI Gom 28 (3.91 t ha^{-1}), whereas the lowest grain yield was recorded in ESWYT 29 (3.20 t ha^{-1}) which was followed by BARI Gom 29 (3.59 t ha^{-1}). Due to water stress grain yield was reduced in all wheat genotypes. But the degree of reduction was different in different genotypes. Under water stress condition, more reduction in grain yield (35.62%) was observed in sensitive genotype ESWYT 29 followed by BARI Gom 28 (30.69%) compared to BARI Gom 29 (17.82%) and BAW 1177 (15.95%). Considering relative performance, the highest relative performance was observed in genotype BAW 1177 (84.04%) followed by BARI Gom 29 (82.17%), whereas genotype ESWYT 29 performed lowest performance (64.37%) which was followed by BARI Gom 28 (69.30%).

Reduced number of spike per m^2 and grains per spike were the major responsible factors for reducing the grain yield under water stress condition in the present experiment. Results from other studies also showed that water stress environment reduced grain yield in wheat compared to control (Baser *et al*. 2004 and Khakwani *et al.* 2011).

3.10 Harvest Index

Table 9 shows that the harvest index was significantly influenced by the interaction effect of water levels and wheat genotypes (P<0.01). The range of harvest index was 40.20% to 44.54% under well water condition, whereas it was 34.62% to 43.25% under water stress condition. Water stress reduced the harvest index for BARI Gom 28 (19.13%), BAW 1177 (2.9%) and ESWYT 29 (15.5%) but it increased for BARI Gom 29 (3.05%) compared to well water condition. Under well water condition BAW 1177 had the highest harvest index (44.54%) followed by BARI Gom 28 (44.38%), while BARI Gom 29 had the lowest harvest index (40.20%) followed by ESWYT 29 (40.97%). Under water stress condition genotype BAW 1177 attained the highest harvest index (43.25%) which was at par with BARI Gom 29 (41.43%), whereas genotype ESWYT 29 had the lowest harvest index (34.62%) which was followed by BARI Gom 28 (35.89%).

As a useful index of assessing the phytomass converted into useful economic yield, the harvest index of the present studied wheat genotypes was significantly varied among genotypes under well water and water stress conditions. This result is similar to that results observed by Qiao *et al.* (2010).

Table 3. Yield and yield components of four wheat genotypes under well water and water stress conditions

Wheat genotypes	Water Levels	1000-grain weight		Biological yield		Grain yield		Harvest index	
		g	RP (%)	t ha^{-1}	RP (%)	t ha^{-1}	RP (%)	%	% change over control
BARI Gom 28	Well water	45.4	93.39	8.81a	85.69	3.91ab	69.30	44.38a	-19.13
	Water stress	42.4		7.55bc		2.71d		35.89bc	
BARI Gom 29	Well water	43.2	95.50	8.93a	79.73	3.59bc	82.17	40.20ab	+3.05
	Water stress	41.26		7.12c		2.95d		41.43a	
BAW 1177	Well water	47.1	96.39	9.43a	86.53	4.20a	84.04	44.54a	-2.9
	Water stress	45.4		8.16b		3.53bc		43.25a	
ESWYT 29	Well water	42.9	94.87	7.81b	76.18	3.2cd	64.37	40.97ab	-15.5
	Water stress	40.7		5.95d		2.06e		34.62c	
Level of significance		NS		*		*			
CV (%)		1.75		2.80		6.17			

In a column, means followed by the same letter(s) did not differ significantly at 5% level by Tukey.

RP = Relative performance

3.11 Stress tolerance index based on above ground biological yield

Stress tolerance index of different wheat genotypes based on above ground biological yield (Figure 2) shows that BAW 1177 had the highest stress tolerance (0.87) followed by BARI Gom 28 (0.86), whereas BARI Gom 29 had the moderate tolerance (0.80) and ESWYT 29 had the lowest stress tolerance (0.76). These stress tolerance index values also indicate that BAW 1177 was less susceptible genotype and ESWYT 29 was the most susceptible genotype, whereas BARI Gom 28 and BARI Gom 29 were moderately tolerant in response to water stress condition.

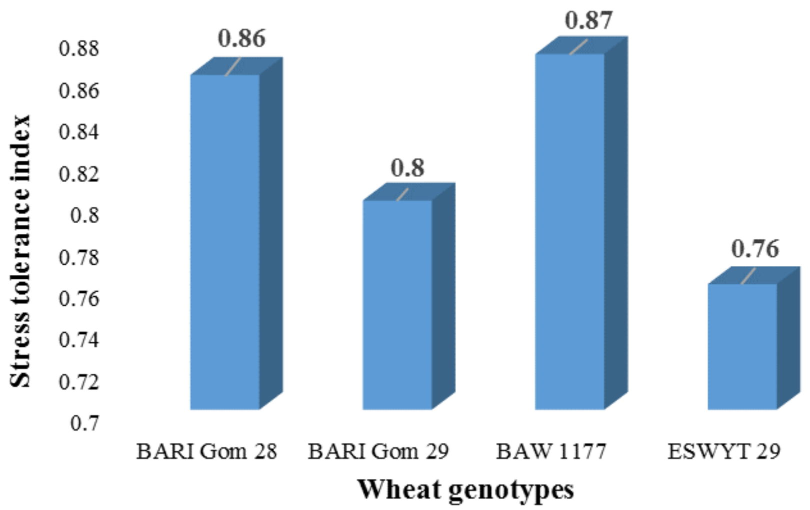

Figure 2: Stress tolerance index of wheat genotypes based on above ground biological yield.

3.12 Stress tolerance index based on grain yield

Figure 3 shows stress tolerance index of different wheat genotypes based on grain yield. BAW 1177 attained the highest stress tolerance (0.84) which was followed by BARI Gom 29 (0.82), whereas ESWYT 29 attained the lowest stress tolerance index (0.64) followed by BARI Gom 28 (0.69). These stress tolerance index values indicate that BAW 1177 was less susceptible genotype and ESWYT 29 was the most susceptible genotype in response to water stress condition based on grain yield.

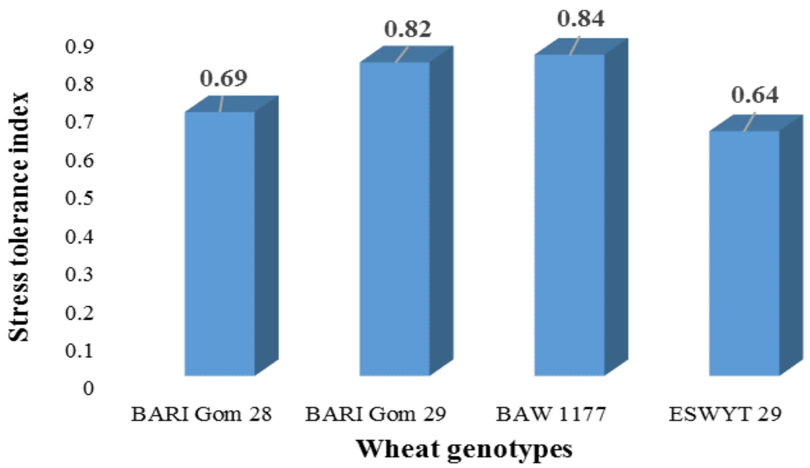

Figure 3: Stress tolerance index of wheat genotypes based on grain yield.

4. Conclusions

Wheat genotypes (BAW 1177, BARI Gom 28 and BARI Gom 29) showed higher value of number of effective tillers plant^{-1}, number of spikes m^{-2}, spike length, grains spike^{-1}, 1000-seed weight, above ground biological yield and grain yield at both well water and water stress conditions compared to genotype ESWYT 29. BAW 1177 was found to be the drought tolerant, BARI Gom 29 and BARI Gom 28 were moderately tolerant and ESWYT 29 was drought susceptible genotype.

References

1. Abd-El-Haleem, S. H. M., Reham, M. A. and Mohamed, S. M. S. (2009). Genetic analysis and RAPD polymorphism in some durum wheat genotypes. Global Biotechnology & Biochemistry, 4, 1-9.
2. Afzal, A. S., Ahmad, Khan, A. and Amin, M. (2006). Comparison of wheat and barley for yield and yield components under different irrigation patterns. *Sarhad Journal of Agriculture, 22(1),* 7-11.
3. Almeselmani, M., Abdullah, F., Hareri, F., Naaesan, M., Ammar, M. A., Kanbar, O. Z. and Saud A. A. (2011). Effect of drought on different physiological characters and yield component in different varieties of Syrian durum wheat. *Journal of Agricultural Science, 3(3),* 127-133.
4. Asana, R. D. and William, R. F. (1965). The effect of temperature stress on grain development in wheat. *Australian Journal of Agriculture Research, 16,* 1-3.
5. Ashraf, M. Y., Sarwar, G., Ashraf, M., Afaf, R. and Sattar, A. (2002). Salinity induced changes in 4-amylase activity during germination and early cotton seedling growth. *Biological Plantarum, 45,* 589-591.

6. Attarbashi, M. R., Galeshi, S., Soltani, A. and Zeinali, E. (2002). Relation of phenology and physiology traits with grain yield in wheat under rainfed conditions. *Iranian Journal of Agriculture Science*, *33(1)*, 21-28.
7. Baque, M. A. (2003). Potassium induced changes in the physiology of wheat plants (*Triticum aestivum* L.) under water stress conditions. M.S. Thesis, Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh.
8. Baser, I. S., Sehirali, H., Orta, H., Erdem, H., Erdem, Y. and Yorgancilar, O. (2004). Effect of different water stresses on the yield and yield components of winter wheat. *Cereal Research Communications*, *32(2)*, 217-223.
9. BBS. (2017). Bangladesh Bureau of Statistics, Statistics and Informatics Division, Ministry of Planning, Government of the people's Republic of Bangladesh.
10. Dash, M. and Panda, S. K. (2001). Salt stress induced changes in growth and enzyme activities in germinating *Phaseolus muingo* seeds. *Biological Plantarum*, 44, 587-589.
11. Goudarzi, M. and Pakniyat, H. (2008). Evaluation of wheat cultivars under salinity stress based on some agronomic and physiological traits. *J. Agriculture and Social Science*, *4(3)*, 35-38.
12. Karim, M. R., Awal, M. A. and Akter, M. (2010). Forecasting of wheat production in Bangladesh. *Bangladesh Journal of Agricultural Research*, 35(1), 17-28.
13. Khakwani, A. A., Dennett, M. D. and Munir, M. (2011). Early growth response of six wheat varieties under artificial osmotic stress condition. *Pakistan Journal of Agriculture Science*, *48(2)*, 121-126.
14. Khaliq, I., Shah, S. A. H., Ahsan, M. and Khalid, M. (1999). Evaluation of spring wheat (*Triticum aestivum* L.) for drought field conditions. A morphological study. *Pakistan Journal of Biological Science*, *2(3)*, 1006-1009.
15. Kilic, H. and Yagbasanlar, T. (2010). The effect of drought stress on grain yield, yield components and some quality traits of durum wheat (*Triticum turgidum* ssp. durum) cultivars. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *38(1)*, 164-170.
16. Mushtaq, T., Hussain, S., Bukhsh, M. A. H. A., Iqbal, J. and Khaliq, T. (2011). Evaluation of two wheat genotypes performance under drought conditions at different growth stages. *Crop and Environment*, *2(2)*, 20-27.
17. Payero, J. O., Tarkalson, D. D., Irmak, S., Davison, D. and Petersen, J. L. (2009). Effect of timing of a deficit-irrigation allocation on corn evapotranspiration, yield, and water use efficiency and dry mass. Agricultural Water Management, 96, 1387-1397.
18. Qiao, Y., Zhang, H., Dong, B., Shi, C., Li, Y., Zhai, H. and Liu, M. (2010). Effects of elevated CO_2 concentration on growth and water use efficiency of winter wheat under two soil water regimes. Agricultural Water Managements, 97, 1742-1748.
19. Rafiq, M., Hussain, A., Ahmad, A., Basra, S. M. A., Wajid, A., Anwa,r J., Ibrahim, M. and Goheer, M. A. (2005). Effect of irrigation on agronomic traits of wheat (*Triticum aestivum* L.). *International Journal of Biology and Biotechnology*, *2*, 751-759.
20. Rana, M. S., Hasan, M. A., Bahadur, M. M. and Islam, M. R. (2017). Physiological evaluation of wheat genotypes for tolerance to water deficit stress. *Bangladesh Agronomy Journal*, 20(2), 37-52.
21. Sikder, S., Begum, F., Baquy, M. A., Islam, M. R. and Kundu, K. K. (2011). Influence of non-irrigated water stress on morphological and yield performance of wheat. *Journal of Bangladesh Society of Agricultural Science and Technoogy*, *8 (3, 4)*, 45-50.