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Screening of wheat genotypes for drought tolerance using a combination of morphological and biochemical traits

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Abstract. The research work was performed during the period from November 2017 to April 2018 in rabi season in the experimental plot of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, to find out the role of morphological and biochemical performance in spring wheat under drought stress. Twenty diverse genotypes, including sixteen lines and four local checks, were evaluated under field conditions. Mean performance, genetic parameters, and Pearson's correlation coefficient were calculated. The most extended plant (84.20 cm) was recorded in genotype Shatabdi, and the highest grain yield/plant (5.57 g) was recorded in Prodip, while the lowest grain yield/plant (4.15 g) was observed in the wheat genotype SAWYT-312. The phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the yield contributing parameters. In the correlation study, a significant positive association was recorded for grain yield/plant with plant height (0.688), number of spike/m^2 (0.269), number of spikelets/spike (0.630), peduncle length (0.640), and weight of 1000 grains (0.201). The positive correlation observed between grain yield, and proline content under-drought stress conditions prove that proline accumulation might ultimately be considered a tool for effectively selecting drought-tolerant genotypes. In consideration of yield contributing characters and yield, Prodip showed better under drought conditions.

Keywords: *Wheat, drought, chlorophyll, proline.*

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1. Introduction

Plant's physiological responses to a deficit of water influence growth and development by directing nutrients to the plants' different parts. Plants are more susceptible to drought during the flowering and seed development stages. Crop plants undergo several environmental stresses, which lead to a significant reduction in production (Farooq et al., 2011). Among these environmental stresses, drought is considered one of the most harmful factors, which cause a significant decrease in crop productivity (Noorka and Heslop-Harrison, 2014). It hampered average growth, impairs water relations, and decrease water use efficiency in plants (Aroca, 2012).

Wheat (*Triticum aestivum* L.) is one of the essential winter crops and is a temperature-sensitive crop. It is the second most crucial grain crop after rice. It was observed that its production is projected to decrease across the globe due to recurring droughts associated with climate change (Knox et al., 2012). Hence, the wheat yields need to be increased to meet growing populations' food demands (Ray et al., 2013). Therefore, breeding drought-tolerant wheat genotypes with relevant morphological and biochemical traits is essential to increase productivity and food security among wheat-growing countries. Phenotyping remains a crucial criterion for screening breeding materials based on drought adaptive and constitutive morpho-physiological characteristics, including yield and its components (Passioura, 2012).

The yield of wheat is meager in Bangladesh. However, it is not an indication of this crop's low yielding potentiality but may be attributed to several reasons. Among different factors, seeds of wide yielding varieties and water availability or drought stress are the significant reasons for yield reduction. Drought is one of the most common factors that limit the productivity of wheat crops in Bangladesh. On average, 44% of Bangladesh farmers do not use irrigation in wheat production and rely on rainfall, responsible for reducing yield up to 34% (Razzaque et al., 1992). Fischer (1999) found that under drought, yield reduction in spring wheat is 60% of productivity. So efforts to identify drought tolerance characters among the existing genotypes to incorporate the tolerance traits into the newly developed varieties are essential to increasing the yield of wheat in Bangladesh's climatic condition.

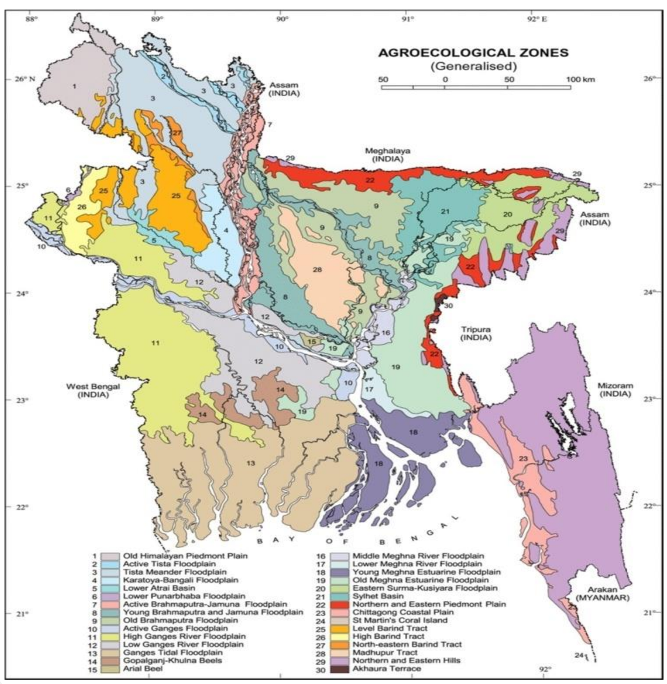
Biochemical analysis, including mannitol, trehalose, and proline contents, has long been proposed to be helpful as a complementary strategy for selecting drought-tolerant genotypes in plant breeding (Mwadzingeni et al., 2016). Proline, an α-amino acid, has been associated with several osmoprotectant roles, including; osmotic adjustment and gene signaling, to activate anti-oxidizing enzymes that scavenge reactive oxygen species (ROS) (De Carvalho et al., 2013). The correlation between proline accumulations at critical growth stages of wheat with drought-stressed yield and other agronomic traits is limited. Exploring proline content under severe stress in a pool of diverse genotypes at critical growth stages and describing its correlation with the yield and its component traits will provide helpful information for rapid germplasm screening when breeding for drought tolerance. Moreover, some of the physiological and biochemical changes related to drought tolerance in wheat genotypes are identified for developing drought-tolerant varieties.

Therefore, a dire need to intensively screen a large pool of wheat breeding lines for drought tolerance using yield, yield-related traits, and proline analyses. So in the context of the situation mentioned above and in respect of wheat cultivation in Bangladesh, the present work was undertaken with twenty wheat genotypes to determine the genotypic variation for drought tolerance among diverse wheat genotypes based on morphological traits and chlorophyll as well as proline analysis.

2. Materials and methods

2.1. Description of the experimental site

The experiment was performed during the period from November 2017 to April 2018 in the rabi season. The present research work was conducted in the experimental area of Sher-e-Bangla Agricultural University, Dhaka (Figure 1). The geographical location of the experimental site was under the subtropical climate. Details of the meteorological data of air temperature, relative humidity, rainfall, and sunshine hour during the experiment were collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, Dhaka, and details have been presented in Table 1.



The experimental site understudy

Figure I. Map showing the experimental site under the study

Table 1. Monthly average of air temperature, relative humidity, and total rainfall of the experimental site during the period from November 2017 to April 2018.				
Month	**Air temperature (°C)***		**Relative humidity (%)***	**Rainfall (mm)**
	Maximum	**Minimum**		
November 2017	26.82	16.05	77	00
December 2017	21.4	13.5	75	00
January 2018	25.5	12.7	67	00
February 2018	28.1	16.2	65	00
March 2018	31.4	19.4	53	12
*Monthly average **Source:** Bangladesh Meteorological Department (Climate and weather division), Agargaon, Dhaka.				

2.2. The geographical location and soil characteristics

The experimental site's geographical location was described as 23°74' N latitude and 90° 35' E longitude at an altitude of 8.6 meters above sea level. The soil belonged to "The Modhupur Tract," AEZ-28 (FAO, 1998). Topsoil was silty clay in texture, olive-gray with standard fine to medium distinct dark yellowish brown mottles. The soil pH was 5.6, and the organic carbon was 0.45%. The experimental area was flat, having an irrigation and drainage system, and above flood levels, and the selected plot was medium-high land. The details have been presented in Table 2.

Table 2. Soil properties of the experimental field analyzed by Soil Resource Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.	
Morphological characteristics of the experimental field	
Morphological features	**Characteristics**
Location	Research Field, SAU, Dhaka
AEZ	Madhupur Tract (AEZ 28)
General Soil Type	Shallow red-brown terrace soil
Land Type	High land
Soil Series	Tejgaon
Topography	Fairly leveled
Physical and chemical properties of the soil before the experiment	
Characteristics	**Values**
Sand (%)	28
Silt (%)	40
Clay (%)	32
Texture	Loamy
pH	5.6
Organic matter (%)	0.82
Total N (%)	0.05
Available P (ppm)	20.01
Exchangeable K (me/100g Soil)	0.11
Available S (ppm)	43
Source: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka	

2.3. Planting materials

Twenty wheat genotypes (Table 3) were used as experimental materials produced in the 2017-2018 cropping season. These genotypes were collected from Wheat Research Centre (WRC) of Bangladesh Agricultural Research Institute (BARI), Rajshahi Center, Rajshahi.

Table 3. Name of wheat genotypes used in the present study			
SL.	Genotypes	SL.	Genotypes
01.	Shatabdi	11.	SAWYT-347
02.	Prodip	12.	DTWYT-02
03.	BARI GOM-28	13.	DTWYT-03
04.	BARI GOM-30	14.	DTWYT-16
05.	SAWYT-303	15.	DTWYT-22
06.	SAWYT-312	16.	SAWYT-326

07.	SAWYT-313	17.	SAWYT-327
08.	SAWYT-317	18.	SAWYT-331
09.	SAWYT-323	19.	SAWYT-344
10.	SAWYT-324	20.	SAWYT-345
SAWYT: Semi-Arid Wheat Yield Trial, DTWYT: Drought Tolerant Wheat Yield Trial			

2.4. Experimental design and layout

The experiment was laid out in randomized complete block design with three replications. The experimental plot area was 600 m^2 with a length of 80 m and a width of 7.0 m. The total area was divided into three equal blocks. Each block was divided into 20 plots where 20 wheat genotypes were allotted at random. There were 60 unit plots altogether in the experiment. The size of each plot was 2.0 m × 1.0 m. The distance was maintained between two blocks, and two plots were 1.0 m and 0.5 m, respectively.

2.5. Land preparation and application of fertilizers and manure

The land was prepared by plowing with a power tiller, followed by harrowing and laddering. All the stubbles and weeds were removed from the field. According to recommended fertilizer doses, TSP, MP, and Gypsum were applied 3 kg, ½ kg, and 1 kg. The entire TSP, MP, and Gypsum, $2/3^{rd}$ of urea, were applied during the land's final preparation. The rest of urea was top-dressed after the first irrigation BARI (2011).

2.6. Sowing of seeds

Furrows were made for sowing the wheat seeds when the land was in proper sowing condition, and seeds were sown on 18 November 2017. Seeds were sown continuously with maintaining 20 cm line to line distance and plant to plant 5 cm. After sowing, seeds were covered with soil and slightly pressed by hand.

2.7. Field Management and inspection

After the germination of seeds, various intercultural operations such as weeding, top dressing of fertilizer, and plant protection measures were accomplished to better grow and develop the wheat seedlings as per the recommendation of Bangladesh Agricultural Research Institute guidelines.

2.8. Drainage and application of drought

Drainage was made for a suitable irrigation channel. At the crown initiation stage, irrigation was a must. Otherwise, the yield would be drastically low. Drought stress was induced by withholding water for 30 days at the heading and anthesis stages. At the end of stress periods, irrigation was given up to field capacity. The control (check) plants were irrigated during the stress period, and all plants were left to grow until grain maturation.

2.9. Thinning, weeding, and plant protection

Weak and densely grown plants were discarded. Various weeds like bathua, nunia, and bonnomasur were weeded out through raker and nirani. 75 g of Autostin fungicide was sprayed with 40 L water due to fungal attack. The attack was not severe and was mitigated efficiently.

2.10. Harvesting, threshing, and cleaning

The crop was harvested manually depending upon the maturity and bundled separately, adequately tagged, and brought to the threshing floor. Enough care was taken during threshing and cleaning of wheat grain. The fresh weight of grain was recorded plot-wise from 1 m^2 area. The grains were dried, cleaned, and weighed for the individual plot. The weight was adjusted to a moisture content of 14%. Yields of wheat grain were recorded and converted into per plant.

2.11. Data Collection

For morphological parameter, data were recorded on days to 50% heading, plant height, number of productive tillers, spike length (cm), number of spikelets/spike, empty spikelet/spike, number of grains/spike to starting of maturity, the weight of 1000 grains and grain yield per plant.

2.12. Chlorophyll content

In order to the biochemical parameter, chlorophyll content of 10 selected leaves was determined from plant samples by using an automatic machine immediately after removal of leaves from plants to avoid rolling and shrinkage.

2.13. Proline analysis

Proline analysis was carried out in the following manner. Samples of the second top leaves from the flag leaf were harvested from the pot experiments' stressed plots. The leaf samples were temporarily stored at ultra-low temperature (-20 °C) then freeze-dried. The dry leaf tissue was ground, and 0.1 g samples were homogenized in 10 mL of 3% aqueous sulfosalicylic acid. Proline extractions were done following the acid-ninhydrin method (Bates et al., 1973). This followed by a UV-visible spectrophotometer analysis of the absorbance of the proline extract in toluene at a wavelength of 520 nm, using a model UV-1800 spectrophotometer, Shimadzu Corporation, Kyoto, Japan. The proline concentration was calculated using the following formula:
Proline content (μg per gram of dry leaf tissue) = [(μg proline/ml) × mL toluene)/115.5 μg/ μmole] / [(g sample)/5].

2.14. Statistical analysis

The data obtained for different characters were statistically analyzed to observe the morphological and biochemical character in spring wheat under drought stress. All the characters' mean values were calculated, and the analysis of variance and variability was performed. Morphological, chlorophyll, and proline data were analyzed. A combined analysis of variance was performed to describe the magnitude of the relationships among agronomic traits, chlorophyll, and proline content. Pearson's correlation coefficients (*r*) were calculated using the SPSS program.

3. Results and discussion

3.1. Evaluation of the mean performance of different yield contributing traits and yield of wheat under drought stress

Mean performance was estimated and presented in Table 4(a, b). Turkey's test revealed a highly significant variation among 20 wheat genotypes in all the studied characters. Significantly high levels of variation for different yield contributing characters and yield revealed the indicative possibilities of improving the genetic yield potential of wheat genotypes under drought stress.

Table 4a. Mean performance of yield contributing characters and yield of spring wheat under drought condition

Genotypes	Days to 50% heading	Plant height (cm)	Number of productive tillers	Spike length (cm)	Number of spikelets
Shatabdi (check)	59.00a-d	82.20a	2.47	12.90ab	18.73ab
Prodip (check)	59.33a-d	78.93a	2.50	12.34ab	18.37ab
BARIGOM-28 (check)	53.33d	65.27bc	3.17	9.11b	13.88b
BARI GOM-30(check)	55.67cd	63.96c	3.33	14.09a	14.53ab
SAWYT-303	67.67a	81.49a	3.13	11.20ab	16.12ab
SAWYT-312	65.67ab	81.80a	2.70	11.53ab	17.54ab
SAWYT-313	62.33a-d	74.78a-c	3.47	10.72ab	15.67ab
SAWYT-317	66.33ab	76.53a	2.70	9.58b	13.67b
SAWYT-323	67.00ab	71.84a-c	2.73	11.56ab	14.60ab
SAWYT-324	65.00a-c	79.11a	3.53	11.07ab	16.20ab
SAWYT-326	66.33ab	77.66a	2.73	11.33ab	15.73ab
SAWYT-327	65.00a-c	80.38a	2.87	11.51ab	18.33ab
SAWYT-331	66.33ab	74.49a-c	2.73	12.41ab	18.23ab
SAWYT-344	68.00a	79.19a	3.27	11.30ab	17.33ab
SAWYT-345	63.67a-c	79.45a	3.00	12.59ab	19.40a
SAWYT-347	60.00a-d	80.15a	2.73	11.89ab	18.68ab
DTWYT-02	59.00a-d	76.35ab	2.87	10.63ab	17.20ab
DTWYT-03	57.67b-d	73.37a-c	2.33	11.17ab	16.91ab
DTWYT-16	57.67b-d	75.46ab	3.13	9.73b	18.20ab
DTWYT-22	58.67a-d	73.98a-c	2.47	10.49ab	14.93ab
Mean	62.18	76.32	2.89	11.36	16.71
Range	53.33-68.00	63.96-82.20	2.33-3.55	9.11-14.09	13.67-19.40
CV(%)	4.98	4.72	15.15	11.87	10.31
HSD (5%)	9.612	11.182	1.362	4.185	5.349

Note. Means with the same letter are not significantly different. HSD = Turkey's Honest Significant Difference (HSD) Test

Table 4b. Mean performance of yield contributing characters and yield of spring wheat under drought condition					
Genotypes	**Empty spikelet/spike**	**Number of grains /plant**	**Days to physical maturity**	**Thousand seeds weight**	**Grain yield per plant**
Shatabdi (check)	0.40	42.07a	103.67a-c	50.03ab	5.50ab
Prodip (check)	1.73	35.47a-d	103.67a-c	48.79a-c	5.57a
BARIGOM-28 (check)	3.07	22.39d	107.00a-c	46.10a-e	5.45ab
BARI GOM-30(check)	2.83	26.67cd	107.00a-c	42.80a-e	5.24a-c
SAWYT-303	1.07	33.13a-d	107.00a-c	46.07a-e	4.80a-e
SAWYT-312	1.13	34.50a-d	108.00a-c	39.73de	4.15e
SAWYT-313	0.83	32.23a-d	109.00a-c	39.47de	4.23de
SAWYT-317	1.23	30.07a-d	110.00a	48.57a-c	4.79a-e
SAWYT-323	1.80	29.80a-d	109.33ab	49.60ab	4.77a-e
SAWYT-324	1.67	33.53a-d	108.67a-c	40.73c-e	4.42c-e
SAWYT-326	1.53	28.17b-d	109.00a-c	38.93e	4.35c-e
SAWYT-327	0.93	34.97a-d	109.00a-c	41.47b-e	4.66a-e
SAWYT-331	2.00	33.43a-d	108.33a-c	47.77a-d	4.95a-e
SAWYT-344	1.67	35.80a-d	106.67a-c	39.10e	4.23de
SAWYT-345	1.07	41.60ab	107.33a-c	48.50a-c	5.13a-d
SAWYT-347	0.37	37.73a-c	106.00a-c	50.40a	5.36ab
DTWYT-02	2.40	30.13a-d	105.00a-c	50.23a	4.89a-e
DTWYT-03	1.60	33.87a-d	104.00a-c	49.43ab	5.01a-e
DTWYT-16	0.40	41.47ab	103.00bc	48.50a-c	4.98a-e
DTWYT-22	1.73	28.60a-d	102.67c	41.87a-e	4.60b-e
Mean	1.47	33.28	106.72	45.40	4.85
Range	0.37-3.07	22.39-42.07	102.67-110.00	38.93-50.40	4.15-5.57
CV(%)	59.08	13.08	1.92	6.12	6.15
HSD (5%)	2.701	13.511	6.347	3.45	0.92
Note. Means with the same letter are not significantly different. HSD = Turkey's Honest Significant Difference (HSD) Test					

The highest days to 50% starting of heading (68.00) was observed in the genotype of SAWYT-344, which was statistically similar (67.67) with the wheat genotypes of SAWYT-303, while the lowest days (53.33) from BARI Gom-28. The most extended plant (82.20 cm) was recorded in genotype Shatabdi the shortest plant (63.96 cm) was found in wheat genotype BARI GOM-30. The longest and the shortest plant may depend on the genotypes, growing condition, and growing location (Hossain et al., 2019; Islam et al., 2019a; Islam et al., 2019b). It was found that plant height decreased to a greater extent when water stress was imposed at the anthesis stage, while the imposition of water stress at the booting stage caused a more significant reduction in plant height (Gupta et al., 2001).

The maximum number of productive tillers (3.53) was found in SAWYT-324, whereas the minimum number of productive tillers (2.33) was observed in the wheat genotype DTWYT-03. The most extended spike length (14.09 cm) was recorded in BARI GOM- 30. On the other hand, the shortest spike length (9.11 cm) was recorded in the wheat genotype BARI Gom-28.

The maximum number of spikelets/spikes (19.40) was found in SAWYT-345, while the lowest number (13.67) was observed in the wheat genotype SAWYT- 317. The highest number of empty spikelet/spike (3.07) was attained in BARI Gom-28, whereas the minimum number empty spikelet/ spike (0.37) was observed in the wheat genotype SAWYT-347. It was reported that the number of spike/m^2 decreased with increasing irrigation intervals (Zarea and Ghodsi, 2004).

The maximum number of grains/plant (42.07) was recorded in Shatabdi, and the minimum number (22.39) in wheat genotype BARI Gom-28. The highest days to starting of maturity (110) were found in genotype SAWYT-317, whereas the lowest days (102.67) were attained in the wheat genotypes DTWYT-22. The highest weight of 1000 grains (50.40 g) was found in SAWYT-347. On the other hand, the lowest weight of 1000 grains (38.93 g) was attained in the wheat genotype SAWYT-326. It was reported that 1000-grain weight was significantly affected by variety (Islam et al., 1993; Hossain et al., 2019; Islam et al., 2019a; Islam et al., 2019b).

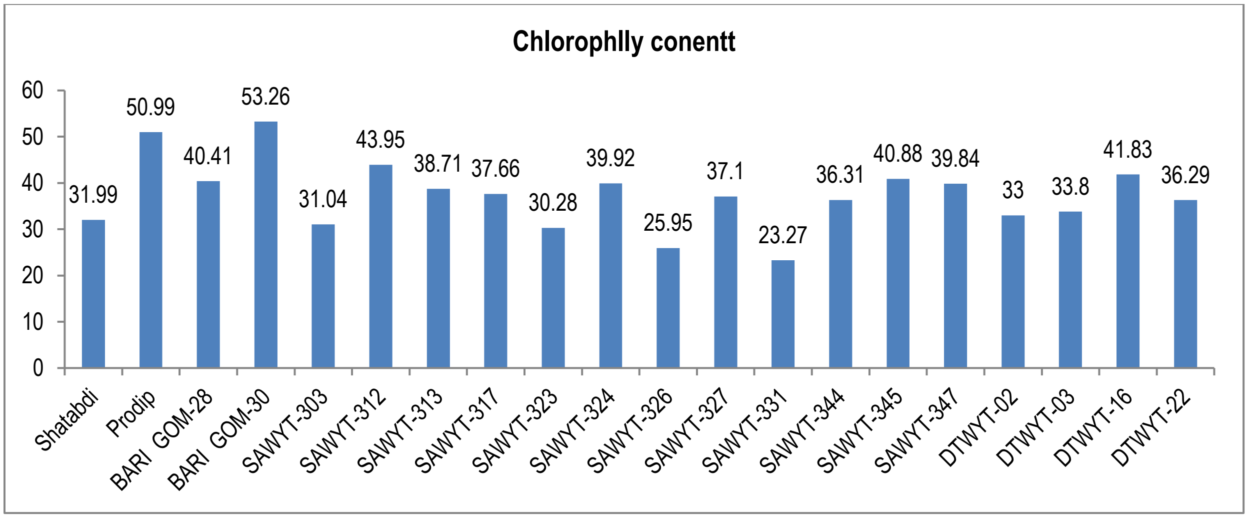


Figure 2. Chlorophyll content for different wheat genotypes

Data revealed that the average chlorophyll was around 37.32, with a range from 23.27 to 53.26. The highest chlorophyll content (53.26) was attained in BARI Gom-30, which was statistically similar (50.99) with wheat variety Prodip, whereas the lowest chlorophyll content (23.27) was found in the wheat genotype DTWYT-331 (Figure 2). It was also reported similar findings earlier (Zarea and Ghodsi, 2004). The chlorophyll content increase owing to the high rate of photosynthesis (Islam et al., 2020) and decrease due to the inhibitory effect of the accumulation of ions for the biosynthesis of the different chlorophyll pigments (Islam et al., 2019c). The genotype variation also may responsible for the increase and decrease of the chlorophyll content.

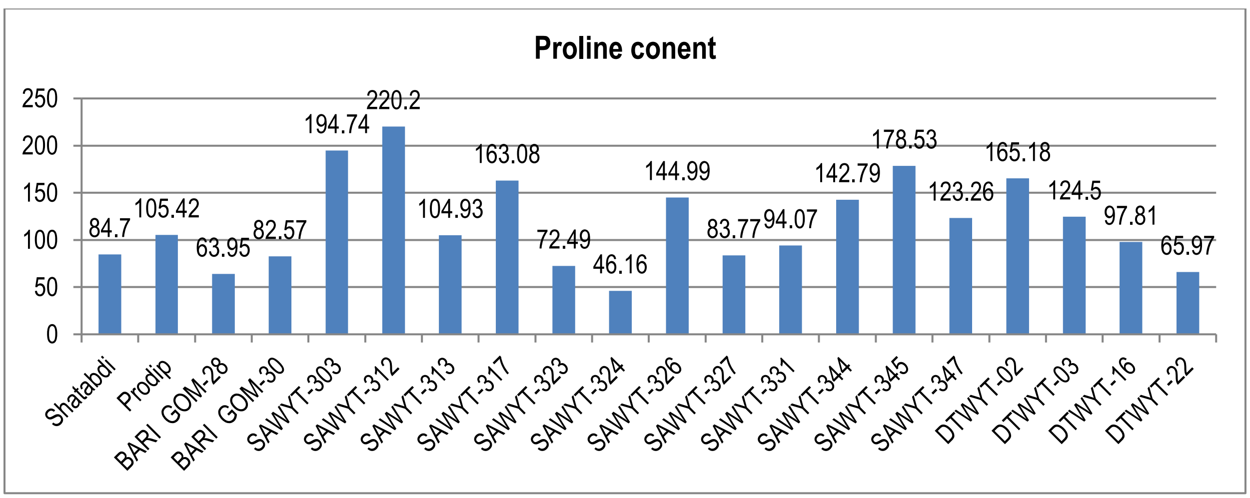


Figure 3. Proline content for different wheat genotypes

The average proline content was 117.96, with a range from 46.16 to 220.20. The highest proline content (220.20) was observed in SAWYT-312, while the lowest proline content (46.16) was found in the wheat genotype SAWYT-324 (Figure 3). The highest grain yield per plant (5.57 g) was recorded in Prodip, while the lowest grain yield per plant (4.15 g) was observed in the wheat genotype SAWYT-312. It was observed that the effect of irrigation treatments on yield and yield contributing characters were statistically significant (Razi-Us-Shams, 1996). Irrigation increased grain yields.

3.2. Variability study for 12 traits of wheat

Genotypic and phenotypic variance, heritability, genetic advance, and genetic advance in the mean percentage were estimated for twelve traits in 20 collected genotypes of wheat and presented in Table 5. Days to starting of 50% heading refers to phenotypic variation (26.19) was higher than the genotypic variance (16.60) that indicated by the slight difference between phenotypic (8.23%) and genotypic (6.55%) co-efficient of variation. In terms of plant height, phenotypic variation (33.53) was higher than the genotypic variance (20.55) that indicated by the slight difference between phenotypic (7.59%) and genotypic (5.94%) co-efficient of variation. High heritability (61.28%) in plant height is attached with moderate genetic advance (7.31) and moderate genetic advance in the percentage of the mean (9.58). Wang et al. (2003) observed a very high broad sense and narrow sense heritability for plant height.

Table 5. Genetic parameters of different yield contributing characters and yield of spring wheat under drought condition

Parameters	σ^2p	σ^2g	σ^2e	PCV (%)	GCV (%)	ECV (%)	H^2b	GA (%)	GA (% mean)
Days to 50% heading	26.19	16.60	9.59	8.23	6.55	4.98	63.38	6.68	10.74
Plant height(cm)	33.53	20.55	12.98	7.59	5.94	4.72	61.28	7.31	9.58
Number of productive tillers	0.25	0.06	0.19	17.23	8.18	15.17	22.53	0.23	8.00
Spike length(cm)	2.60	0.79	1.82	14.21	7.81	11.87	30.20	1.00	8.84
Number of spikelet /spike	5.07	2.10	2.97	13.48	8.67	10.31	41.44	1.92	11.50
Empty spikelet/spike	1.06	0.31	0.76	69.97	37.49	59.08	28.71	0.61	41.38
Number of grains /plant	38.59	19.63	18.95	18.66	13.31	13.08	50.89	6.51	19.57
Days to physical maturity	8.14	3.95	4.18	2.67	1.86	1.92	48.60	2.86	2.68
Thousand seeds weight	23.90	16.18	7.72	10.77	8.86	6.12	67.70	6.82	15.02
Chlorophyll content	55.64	52.71	2.93	19.98	19.45	4.58	94.74	14.56	39.00
Proline content	2395.12	2226.73	168.40	41.49	40.01	11.00	92.97	93.73	79.46
Grain yield per plant	0.25	0.16	0.09	10.34	8.31	6.15	64.60	0.67	13.75

Note. σ^2p = phenotypic variation, σ^2g genotypic variation= , σ^2e = environmental variation, PCV = phenotypic coefficient of variation, GCV = genotypic coefficient of variation, ECV = environmental coefficient of variation, H^2b = heritability in broad sense, GA = Genetic advance.

Phenotypic variation (0.25) was higher than the genotypic variance (0.06) for the number of effective tillers content, indicating that strong environmental influence on these characters was supported by the slight difference between phenotypic (17.23%) and genotypic (8.18%) co-efficient of variation. Moderate heritability (22.53%) in the number of productive tillers attached with low genetic advance (0.23) and low genetic advance in the percentage of the mean (8). Spike length in refers to phenotypic variation (2.60) was higher than the genotypic variance (0.79) that indicated that strong environmental influence on these characters was supported by the slight difference between phenotypic (14.21%) and genotypic (7.81%) co-efficient of variation. High heritability (30.20%) in spike length attached with low genetic advance (1.0) and low genetic advance in the percentage of the mean (8.84). Phenotypic variation (5.07) was higher than the genotypic variance (2.10) in consideration of the number of spikelets/spike that is indicating a narrow difference between phenotypic (13.48%) and genotypic (8.67%) co-efficient of variation. High heritability (41.44%) in the number of spikelet's/spike attached with low genetic advance (1.92) and moderate genetic advance in the percentage of the mean (11.50).

The number of empty spikelets/ spikes refers that phenotypic variation (1.06) was higher than the genotypic variance (0.31) that indicates that the little difference between phenotypic (69.97%) and genotypic (37.49%) co-efficient of variation. Moderate heritability (28.71%) in the number of empty spikelets/spikes attached with low genetic advance (0.61) and high genetic advance in the percentage of the mean (41.38). The number of grains/plant refers that phenotypic variation (38.59) was higher than the genotypic variance (19.63) that indicated that strong environmental influence on these characters was supported by a narrow difference between phenotypic (18.66%) and genotypic (13.31%) co-efficient of variation. High heritability (50.89%) in the number of grains/plant attached with low genetic advance (6.51) and moderate genetic advance in the percentage of the mean (19.57).

Phenotypic variation (8.14) was higher than the genotypic variance (3,95) in terms of days to physical maturity that indicating that strong environmental influence on these characters was supported by a narrow difference between phenotypic (2.67%) and genotypic (1.86%) co-efficient of variation. Moderate heritability (40.60%) in days to physical maturity attached with low genetic advance (2.86) and low genetic advance in the percentage of the mean (2.68). The weight of 1000 grains in consideration of phenotypic variation (23.90) was higher than the genotypic variance (16.18) that indicated that strong environmental influence on these characters was supported by a narrow difference between phenotypic (10.77%) and genotypic (8.86%) co-efficient of variation. High heritability (67.70%) in weight of 1000 grains attached with high genetic advance (6.82) and high genetic advance in the percentage of the mean (15.02).

In terms of chlorophyll content, phenotypic variation (55.64) was higher than the genotypic variance (52.71) that indicated that strong environmental influence on these characters was supported by a narrow difference between phenotypic (19.98%) and genotypic (19.45%) co-efficient of variation. High heritability (94.74%) in chlorophyll content was associated with moderate genetic advance (14.56). Proline content in consideration of phenotypic variation (2395.12) was higher than the genotypic variance (2226.73), indicating that the slight difference between phenotypic (41.49%) and genotypic (40.01%) co-efficient of variation. High heritability (92.97%) in proline content is attached with high genetic advance (93.73) and high genetic advance in the percentage of the mean (79.46). For grain yield per plant in the context of phenotypic variation (0.25) was higher than the genotypic variance (0.16) that indicated that strong environmental influence on these characters was supported by the slight difference between phenotypic (10.34%) and genotypic (8.31%) co-efficient of variation. High heritability (64.60%) in grain yield per plant is attached with low genetic advance (0.67) and high genetic advance in the percentage of the mean (13.75).

4.3. Correlation Matrix

In correlation study, Table 6 showed that significant negative association was recorded for grain yield per plant of wheat genotypes with days to 50% of heading (-0.397), days to physical maturity (-0.344), while the non-significant negative association for plant height (-0.166), number of productive tillers (-0.226), proline content (-0.190). On the other hand, a significant positive association was recorded for grain yield per plant with thousand seed weight (0.707) and chlorophyll content (0.244), while the non-significant positive association was observed with spike length (0.087), spikelets per spike (0.147), empty spike per plant (0.090), and grain per plant (0.150). It was reported that grain yield per plant directly correlates with the number of spikes per plant and 1000-grain weight in some advanced wheat lines (Kumar and Shukia, 2002). It was found that positive direct effects of biological yield per plant, number of grains per ear, tillers per plant, 1000 kernel weight, days to heading, and days to maturity on grain yield (Payal et al., 2007).

Table 6. Correlation matrix of different yield contributing characters and yield of wheat under drought condition Pearson's correlation coefficients (r) describing the association of twelve traits of 20 wheat genotypes evaluated under drought stress

	PH	NT	SL	SPS	ESP	GPP	DM	TSW	CC	PC	GYP
DH	0.331**	0.138	0.109	0.056	-0.084	0.062	0.451**	-0.201	-0.388**	0361**	-0.397**
PH		-0.115	-0.004	0.508**	-0.466**	0.565**	-0.122	-0.000	-0.176	0.415**	-0.166
NT			0.041	-0.015	0.037	-0.018	0.276*	-0.349**	0.104	-0.107	-0.226
SL				0.309**	0.062	0.208	0.112	-0.028	0.131	-0.023	0.087
SPS					-0.314**	0.785**	-0.215	0.186	0.003	0.158	0.147
ESP						-0.662**	-0.022	-0.124	0.105	-0.122	0.090
GPP							-0.200	0.279*	0.052	0.144	0.150
DM								-0.193	-0.183	0.039	-0.344**
TSW									-0.042	0.005	0.707**
CC										-0.047	0.244*
PC											-0.190

Note. DH, days to 50% heading; PH, plant height; NT, number of productive tillers; SL, spike length; SPS, number of spikelets per spike; ESP, empty spikelets per plant; DM, days to maturity; TSW, thousand seed weight; CC, chlorophyll content; PC, proline content; GYP, grain yield per plant. **: Significant at 0.01 level of probability *: Significant at 0.05 level of probability.

Considering yield contributing characters and yield, Prodip performed better under drought conditions, followed by DTWYT-22, SAWYT-326, SAWYT-331, Shatabdi, BARI Gom-28, BARI Gom-30. The phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the yield contributing traits indicating a strong environmental influence on the studied characters. Correlation analysis revealed that the characters' thousand seed weight and chlorophyll content positively correlated with yield per plant. Under stress, most of the genotypes were scattered in the positive side of the first principal component, with genotypes such as SAWYT-303, SAWYT-326, SAWYT-331, and SAWYT-344 excelling in yield, which was contributed mainly through high spikelets per spike, grain per plant, spike length and thousand seed weight, as well as optimum values for other yield components. The positive correlation of grain yield and proline content found under-drought stress conditions provides evidence that proline accumulation might ultimately be considered a tool for effective selection. Further studies are required to quantify the proline content of diverse genotypes at different stress levels to explore the rate of proline accumulation in different genotypes during stress exposure and yield potential of genotypes.

4. Conclusion

Mean performance, variability, and correlation matrix were done on yield contributing characters and yield of wheat genotypes under drought stress. Results found that the most extended plant (84.20 cm) was recorded in genotype Shatabdi, while the shortest plant (63.96 cm) was found in wheat genotype BARI GOM-30. The highest grain yield per plant (5.57 g) was recorded in Prodip, while the lowest grain yield per plant (4.15 g) was observed in the wheat genotype SAWYT-312. Considering yield contributing characters and yield, Prodip performed better under drought conditions, followed by DTWYT-22, SAWYT-326, SAWYT-331, Shatabdi, BARI Gom-28, BARI Gom-30. It was observed that the phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the yield contributing traits indicating a strong environmental influence on the studied characters. Results showed that the significant negative association was recorded for grain yield per plant of wheat genotypes with days to 50% of heading (-0.397), days to physical maturity (-0.166), and root number (-0.343), while the non-significant negative association for several grains/spike (-0.183), chlorophyll content (-0.097), dry matter content (-0.003) and root length (-0.058). On the other hand, a significant positive association was recorded for grain yield per plant with plant height (0.688), number of spike/m^2 (0.269), number of spikelets/spike (0.630), peduncle length (0.640), and weight of 1000 grains (0.201). The positive correlation observed between grain yield, and proline content under-drought stress conditions prove that proline accumulation might ultimately be considered a tool for effectively selecting drought-tolerant genotypes. In consideration of yield contributing characters and yield, Prodip performed better under drought conditions, followed by DTWYT-22, SAWYT-326, SAWYT-331, Shatabdi, BARI Gom-28, and BARI Gom-30. The proline content high found in SAWYT-312 (220.2), and also found in SAWYT-303 (194.74), SAWYT-345 (178.53), and lowest in SAWYT-324 (46.16). Further studies are required to quantify the proline content of diverse genotypes at different stress levels to explore the rate of proline accumulation in different genotypes during stress exposure and yield potential of genotypes.

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