International Journal of Agronomy and Agricultural Research (IJAAR)
ISSN: 2223-7054 (Print) 2225-3610 (Online)
http://www.innspub.net
Vol. 23, No. 3, p. 1-9, 2023

RESEARCH PAPER OPEN ACCESS

Searching high yielding durum wheat genotype (s) through the assessment of the physiology, yield, and yield contributing attributes

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Article published on September 11, 2023

Key words: Durum wheat, Physiology, Grain yield

Abstract

Until any variety of durum wheat was released in Bangladesh. However, its demand increases in the country for its prepared quality of macaroni and pasta, and multidimensional uses. In fact, Bangladesh meets up the need of durum wheat completely importing from the foreign countries. Fifty genotypes of durum wheat were evaluated to search out a high yielding genotype (s) whereas BDW8 advanced line was used as check. Each genotype/entry (E) was sown in a plot (6 rows having each row 2.5m length) maintaining 20cm spacing between two rows. The experiment was laid out in the randomized complete block design with three replications. In the study, the genotype E-726 demonstrated the highest spikes m^{-2}, grain $spike^{-1}$, thousand grain weight (TGW) and grain yield than other genotypes whereas E-708 stood the second position regarding these yield and yield contributing attributes followed by E-725 while BDW8 line exhibited grain yield only 5.67 t ha^{-1}. Oppositely, the lowest grain yield was produced by E-746 followed by E-749. Moreover, the genotypes E-718, E-719 and E-721 also exhibited comparatively more grain yield than BDW8. Therefore, the genotypes E-708, E-718, E-719, E-721, E-725 and E-726 may be the potential high yielding genotype (s), and should be further examined to verify their consistency to release a variety for durum wheat production in Bangladesh.

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Introduction

Durum wheat (*Triticum turgidum* subsp. *durum*) is the second most cultivated species after common wheat (*Triticum aestivum* L.) in the world, and called macaroni wheat or pasta wheat. Durum wheat is used worldwide for several food products, such as pasta, couscous, unleavened bread, bulgur, and mote, among others (Alemu, 2017). These products constitute the main staple food in North Africa and for many world areas. These uses are mainly due to its unique qualities such as its hardness, high protein content, and gluten strength. In addition, it is preferred for the production of pasta or macaroni products; mainly because of its elevated level of yellow pigments and appropriate protein and gluten characteristics (Alemu, 2017; Troccoli *et al.*, 2000).

Durum wheat was developed by artificial selection of the domestication emmer wheat strains formerly grown in Central Europe and Near East around 7000 BC. It is majorly grown in the Middle East. It is a tetraploid species of wheat having 4 sets of chromosomes for a total of 28. It originated through intergeneric hybridization and polyploidization involving two diploid (having 2 sets of chromosomes) grass species: *T. urartu* (2n=2x=14, AA genome) and a B-genome diploid related to *Aegilops speltoides* (2n=2x=14, SS genome) and is thus an allotetraploid (having 4 sets of chromosomes, from unlike parents) species (Kubaláková *et al.*, 2005; Alemu, 2017).

Short duration or early maturing durum wheat variety is needed for the cultivation in Bangladesh. Therefore, days to heading and maturity are the most crucial considerable attributes for developing durum wheat variety. Because, the winter period in the country is very short (November to February). Moreover, durum wheat is cool loving crop. The optimum sowing time of durum wheat in Bangladesh is from 15 November to 30, preferred upto 7 December in the northern part of Bangladesh (Alam *et al.*, 2014). When this period wheat is sown, grain filling stage turns over in cold resulting in grain formation well (Alam *et al.*, 2013b; Alam *et al.*, 2013a; Monwar *et al.*, 2021). Timely heading of durum wheat in the country is crucial as late sowing of wheat faces dry and hot weather whereas pollen grains dry, and loss its movement from stigma to ovary (Alam *et al.*, 2013c). Dry matter partitioning is reduced i.e., the flow of assimilates from source organs via transport path to sink organs is not occurred properly. Ultimately, crop fell into early maturity, deformed, small and shriveled grains were formed and grain yield were reduced (González-Ribot *et al.*, 2017).

Plant height is the important factor on which plant lodging depends as its type. Dwarf sized durum wheat variety is desired to protect its lodging during flowering to maturity. Modern genotypes of durum wheat are semi-dwarfs since they carry one of the Rht genes (Mellado, 2007; Sip *et al.*, 2009), and this has been positive for grain yield. However, it has been found that greater plant height has a positive effect on yield in dry Mediterranean rainfed conditions; for this reason, it is desirable that the genotypes maintain their height in arid rainfed areas (Zapata *et al.*, 2004; Royo *et al.*, 2014) compared to irrigated areas. Yield components are agronomic traits that provide an opportunity to improve yield in irrigated condition, along with morphological and physiological traits. The yield components, which together cover all the period of crop development, are the number of spike m^{-2} and TGW. Grain weight was found to be associated with yield in rainfed areas (Rharrabti *et al.*, 2001; Royo *et al.*, 2002; Nouri-Ganbalani *et al.*, 2009). Several studies reported grain weight as the yield component with the highest heritability in bread wheat and Durum wheat (Rharrabti *et al.*, 2003; Wang *et al.*, 2009; Li *et al.*, 2015). Alam *et al.* (2014) depicted that TGW influenced the grain yield of bread wheat.

The annual durum wheat production was approximately 36.0 million ton in 2017 worldwide (Chris, 2017). However, as the world population is predicted to rise to 9.1 billion by 2050 (Aalami *et al.*, 2007), which is 34% higher than the current population, breeding cereals, including durum wheat, with improved yield and quality performance has become urgent and relevant. In Bangladesh, the demand and uses of pasta and macaroni are being increased day by day. These food items are also made from durum wheat. Bangladesh imported 55.28 million ton of wheat in fiscal 2018-19, which was 84.3% its annual consumption of 65.57 million ton, according to the food ministry and the US Department of Agriculture (BBS, 2020). Bangladesh Wheat and Maize Research Institute (Previously known as Wheat Research Centre) developed 33 bread wheat varieties upto 2018 (BWMRI, 2018). Still now, any variety of durum wheat is not released. Therefore, the experiment was undertaken to evaluate the performances of several durum wheat genotypes in respect of physiology, yield and yield-contributing characters; thereafter very soon, the release of a high yielding durum wheat variety is possible for widely cultivation in Bangladesh.

Materials and methods

Plant materials, location and soil characteristics

The experiment was conducted with fifty durum wheat genotypes provided by CYMMIT, Mexico in the 2019-20 season (November to March) in the research field of Bangladesh Wheat and Maize Research Institute (BWMRI), Nashipur, Dinajpur, Bangladesh (Quayyum, 1994). The soil of the research field of BWMRI belongs to under the Old Himalayan Piedmont Plain designated as Agro Ecological Zone (AEZ) # 1 (FAO/UNDP, 1988), characterized by flood free highland, fine in texture (sandy loam and silt loam), poor in organic matter. It is situated in northern part of Bangladesh and geographically the area lies between 25°38´ N and 88°41´ E and 38.20m above the sea level.

Design and experimental procedures

The experiment was accommodated in randomized complete block design with three replications. Seeds were sown in line with 20cm row spacing in 2-4cm soil depth on November 30, 2019 in irrigated condition. The unit plot size was consisting of 6 rows and each line length was 2.5m. The recommended crop management practices and data recording of different agronomic characters were performed as described by the guidelines of BWMRI (2018).

Fertilizer application and seed treatment

The land was ploughed four times horizontally with tractor and harrow followed by 12-15cm depth. Each sub-plots were fertilized @ 100-27-50-20-1-4.5-5000kg ha^{-1} as N-P-K-S-B-Zn-Cowdung as the source of urea, TSP, MoP, Gypsum, Boric acid, and Zinc sulphate, respectively. TSP, MoP, Gypsum, Boric acid, Zinc sulphate, Cowdung and two-third of urea were applied as basal dose at last ploughed. Seeds were treated with Provax 200 WP@3g/kg seed, containing Carboxin and Thiram. Seeds @100kg ha^{-1} were sown continuously in line.

Intercultural operations

One-third urea was applied as top-dress at crown root initiation stage followed by first irrigation at 20 DAS (days after sowing). The second irrigation was applied at late booting stage (50 DAS) and another was applied at early grain filling stage (70 DAS). Each sub-plot was kept free from weeds by applying affinity @2.5g/litre water at 27 DAS after 1st irrigation. Nativo was sprayed two times @0.3g/L water, one just before spike initiation and another was applied 15 days after first spray to control *Bipolaris* leaf blight and other diseases. Each genotype was harvested after maturity.

Harvesting, processing, and data recording

In the Zadoks stage 9.2, the crop was harvested, unit plot was bundled separately, tagged, and taken to a threshing floor (Zadoks *et al.*, 1974). The bundles were thoroughly dried under bright sunshine until dried, and then threshed. The threshed grains were again dried with sunshine, and weighed. Lastly grain yield was expressed into ton/hectare (t ha^{-1}). Thousand grains were counted, weighed, and expressed in gram (g). To obtain the actual yield, grain yield weight was adjusted at 12% moisture by the following equation (BWMRI, 2018): Grain yield adjusted by using the following formula:

$$Yadj = Y_{AC} \ X \ \frac{(100 - M_{AC})}{(100 - M_{ST})}$$

Where,

Yadj = Adjusted yield

Y_{AC} = Yield at actual moisture percent

M_{AC} = Actual moisture percent

M_{ST} = Standard moisture percent

Statistical Analysis

The statistical analysis was performed by SPSS (version 23). Treatment means were compared for significance by the least significant difference (LSD) test at $p = 0.05$.

Results and Discussion

Days to heading

Timely heading is the important factor to attain maximum yield of durum wheat since durum wheat likes low temperature during grain filling stage. In the study, days to heading of various genotypes were significantly difference (Table 1). The check genotype BDW8 exhibited maximum heading days, and then maximum heading time was observed in the genotypes E-743 followed by E-725, E-730, E-741, E-745 and E-750 genotypes, and minimum day to heading was found in the genotypes E-702, E-707, E-706 (62.0 d) followed by E-718 (63 d) (Table 1). González-Ribot *et al.* (2017) and Khan *et al.* (2013) supported these results.

Table 1. Mean performance of the physiology, yield and yield contributing attributes of durum wheat genotypes.

Genotypes	Days to heading (d)	Days to maturity (d)	Plant height (cm)	Spikes m^{-2}	Spike length (cm)	Spikelet spike^{-1}	Grain spike^{-1}	Thousand grain weight (g)	Grain yield (t ha^{-1})
BDW8	76.5	119	89.0	474	7.00	18.0	66.5	43.9	5.67
E-701	66.5	117	87.8	450	7.75	19.0	62.5	41.0	6.65
E-702	62.0	114	91.3	438	8.00	19.5	73.0	43.1	5.06
E-703	69.0	115	94.8	470	8.00	18.0	55.5	46.0	5.81
E-704	64.5	111	86.9	446	7.95	19.5	75.0	39.7	5.34
E-705	70.0	116	97.3	507	8.25	20.5	74.5	34.2	5.24
E-706	62.0	110	88.9	463	7.50	18.0	67.0	39.0	5.43
E-707	62.0	115	87.6	544	8.00	19.0	64.5	32.7	6.19
E-708*	69.5	115	97.9	540	7.45	19.0	67.5	42.2	7.19
E-709	71.0	115	98.2	504	7.75	19.0	73.5	38.9	6.22
E-710	68.5	109	91.0	461	8.00	19.5	75.5	37.2	6.09
E-711	71.0	112	98.0	486	8.00	18.5	70.0	42.5	5.40
E-712	67.5	114	88.0	444	7.50	18.5	66.5	35.3	4.89
E -713	64.5	109	83.2	476	6.75	18.5	65.5	34.1	5.20
E-714	69.0	115	97.0	499	7.25	18.0	71.5	41.9	5.80
E-715	71.0	120	94.9	500	7.15	19.0	71.0	40.1	5.63
E-716	69.0	120	87.7	540	7.00	18.0	62.5	38.4	5.68
E-717	66.5	116	90.3	510	6.75	15.5	53.0	44.9	5.70
E-718*	63.0	112	85.4	504	7.50	17.0	61.0	41.2	6.53
E-719*	67.0	117	81.1	528	7.60	18.5	67.5	42.9	6.57
E-720	67.0	111	87.9	525	7.50	19.0	73.0	38.4	6.41
E-721*	67.0	117	91.5	515	7.50	19.5	77.0	41.6	6.49
E-722	65.0	117	85.4	410	7.50	19.5	57.5	38.1	5.26
E-723	72.5	113	84.5	505	6.75	18.0	66.0	45.1	5.29
E-724	63.5	115	83.2	466	6.75	18.0	58.0	37.9	5.50
E-725*	73.0	119	95.2	546	7.15	18.5	78.0	39.9	7.01
E-726*	70.5	114	98.0	513	6.91	19.5	69.5	40.3	7.44
E-727	72.0	115	95.3	451	6.75	19.0	67.0	40.3	5.48
E-728	69.0	118	96.7	490	6.00	16.5	64.0	44.4	5.73
E-729	70.0	116	88.7	454	6.75	19.0	74.5	31.9	5.38
E-730	73.0	118	98.4	529	6.75	18.0	79.5	40.7	5.95
E-731	72.5	115	90.8	474	6.25	18.5	89.5	36.7	5.16
E-732	74.0	110	90.9	496	7.75	20.0	79.0	39.3	5.75
E-733*	66.5	110	81.8	507	8.00	19.5	66.5	34.9	6.42
E-734	69.0	115	86.0	504	7.00	19.5	71.0	41.5	6.30
E-735	69.0	110	87.5	469	7.25	19.0	71.5	38.1	5.96
E-736	69.5	111	84.5	453	7.40	17.5	65.5	36.9	5.70
E-737	69.5	114	99.6	552	8.25	22.0	85.5	37.4	5.43
E-738	64.0	111	89.1	470	7.25	19.0	64.0	40.6	5.37
E-739	65.0	118	96.3	504	6.75	19.5	59.0	45.5	5.98
E-740	63.5	110	86.8	415	6.60	19.5	83.0	30.6	5.83
E-741*	73.0	120	94.7	551	7.50	19.0	84.5	36.9	6.33
E-742	71.0	116	99.6	531	8.50	20.5	77.5	38.4	6.22
E-743	75.5	118	96.4	510	7.60	18.0	68.0	42.7	6.12
E-744	70.0	121	98.4	630	9.20	19.5	65.5	45.5	5.45
E-745	73.0	113	94.3	478	8.00	19.5	72.5	41.6	5.19
E-746	61.0	108	81.0	467	7.00	18.0	68.0	27.2	2.93
E-747	72.0	120	93.3	599	7.75	19.0	64.0	40.2	5.68
E-748	71.0	118	93.0	501	7.25	18.5	66.5	33.1	4.75
E-749	69.0	112	84.5	456	7.25	18.0	79.5	32.8	4.48
E-750	73.0	116	86.7	585	8.00	20.0	80.0	45.3	6.21
F-test	**	**	**	**	**	NS	**	**	**
CV	4.34	3.87	5.73	55.45	0.70	1.46	9.31	5.10	0.84
LSD (5%)	18.8	15.0	32.8	3075	0.50	2.1	86.7	26.0	0.70

E = Entry, * indicates a selected durum line, * indicates significance at the 5% probability level, **indicates significance at the 1% probability level, NS = Non-significance at the 5.0% probability level, CV = Co-efficient of Variation, LSD = Least significant difference at the 5% probability level.

Days to maturity

Days to maturity of various durum wheat genotypes were observed significantly difference (Table 1). The highest days to maturity was observed in the genotypes E-744 followed by E-715 and E-716 genotypes whereas the check BDW8 (and also E-725 genotype) demonstrated 119 d (Table 1). On the other hand, the lowest days to maturity was found in the genotypes E-746 (followed by E-732, E-733, E-735 and E-740 (Table 1). The similar results were found by Khan *et al.* (2013) and Garcı´a del Moral *et al.* (2003).

Plant height

Plant height is the important factor to protect the lodging of durum wheat. The genotypes E-719 demonstrated the lowest plant height while E-742 and E-737 exhibited the highest plant height (99.6cm) followed by E-744, E-711 and E-726. The check genotype BDW8 exhibited comparatively medium plant height (89.0cm) than other genotypes (Table 1).

Spikes m^{-2}

Number of spikes m^{-2} is the crucial factor of yield contributing characters. After maturity how many of spike existed with fertile grain in the field on which yield production depends (González-Ribot *et al.*, 2017). In the investigation, the highest spikes m^{-2} was observed in the genotype E-744 followed by E-747, and the lowest one by E-740 (415) (Table 1) whereas the check BDW8 demonstrated 474 Spikes m^{-2} (Table 1). These results were supported by González-Ribot *et al.* (2017); Khan *et al.* (2013) and Garcı´a del Moral *et al.* (2003).

Spike length

The highest spike length was obtained by the genotype E-744 followed by E-742, and lowest one by the genotype E-728 followed by E-731 while the check genotype BDW8 showed 7.00cm spike length (Table 1). This was evidenced by Khan *et al.* (2013).

Spikelet spike^{-1}

The number of spikelets per spike is another important factor to get higher yield. The highest spikelet spike^{-1} was obtained by the genotype E-737 followed by E-705 and E-742 and, and lowest one by the genotype E-717 followed by E-728 while the check genotypes BDW8 showed 18.0cm spikelet spike^{-1}. The genotypes E-743, E-746, E-749, E-703, E-706, E-714, E-716, E-723 and E-724 demonstrated same number spikelet spike^{-1} like BDW8 (Table 1). These results were supported by Khan *et al.* (2013) and Garcı´a del Moral *et al.* (2003).

Grain spike^{-1}

The number of grains per spike has been traditionally utilized to improve wheat yield under irrigation (Slafer *et al.*, 1996, 2014). Heat stress, singly or in combination with drought, it is common constraint during anthesis and grain filling stages in many cereal crops of temperate region (Nahar, *et al.*, 2010). The genotype E-717 exhibited the lowest grain spike^{-1} whereas the highest grain spike^{-1} was obtained by the genotype E-731 followed by E-737.

Thousand grain weight

TGW is the most important factor of the yield contributing characters. It has the great role to increase/reduce yield of a wheat genotype (Alam *et al.*, 2013a; Alam *et al.*, 2014; Khan *et al.*, 2013). In the trial, the max TGW was demonstrated by the genotype E-703 followed by E-744, and the lowest TGW was exhibited by E-746 followed by E-740 while 43.9g TGW was obtained by the check genotype BDW8 (Table 1).

Grain Yield

The highest grain yield was yielded by the genotype E-726 followed by the genotype E-708, then after genotype E-725. Oppositely, the lowest grain yield was obtained by the genotype E-746 followed by the genotype E-749, then after genotype E-712 while BDW8 line exhibited grain yield 5.67 t ha^{-1} (Table 1). In addition, the genotypes E-718, E-719 and E-721 also demonstrated comparatively better performances than BDW8 and other genotypes (Table 1). The yield contributing characters spike m^{-2}, grain spike^{-1} and TGW had the most contribution to produce the maximum grain yield of durum wheat (Garcı´a del Moral *et al.*, 2003). Nofouzi (2018) summarized that plant height, spike length, peduncle length and grain spike^{-1} had positive correlations and significant with grain yield of durum wheat. Khan *et al.* (2013)

pointed out that to select the potential durum wheat variety, more emphasis should be given on heading days and plant height along with TGW, spikes m^{-2} and grain $spike^{-1}$ during for durum wheat improvement. According to the evaluation of yield contributing characters, the genotypes E-718, E-719, and E-721 showed also comparatively higher performances than BDW8 used as check (Table 1).

Conclusion

The genotype E-726 demonstrated the highest spikes m^{-2}, grain $spike^{-1}$, TGW and grain yield than other genotypes whereas E-708 stood the second position regarding these yield and yield contributing attributes followed by E-725 while BDW8 line exhibited grain yield only 5.67 t ha^{-1}. Oppositely, the lowest grain yield was produced by E-746 followed by E-749. Moreover, the genotypes E-718, E-719 and E-721 also exhibited comparatively more grain yield than BDW8. Therefore, the genotypes E-708, E-718, E-719, E-721, E-725 and E-726 may be the potential high yielding genotype (s), and should be further examined to verify their consistency to release a variety for durum wheat production in Bangladesh.

Acknowledgements

Sincere gratitude to the editors and reviewers for their insightful comments and suggestions. The work was performed with the core research fund of the Ministry of Agriculture, The Government of the People's Republic of Bangladesh [Grant number 135015200; Fiscal years of 2017, 2018 and 2019] allotted to the Bangladesh Wheat and Maize Research Institute Nashipur, Dinajpur, 5200, Bangladesh.

Conflict of interest

There is no conflict of interest of the authors.

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