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EVALUATION OF SHORT DAY LOCAL AND EXOTIC ONION GENOTYPES

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Abstract

Onion is one of the important spices of daily dishes in Bangladesh and are shortage in production of the crop. Due to high photosensitivity in onion, only short-day types are suitable for cultivation in the particular agroclimatic condition of the country. But lack of high yielding potentiality in the existing cultivar along with limited variability within the available germplasm is the major drawback in onion production. To mitigate the problem, the present investigation was done to identify suitable short-day onion genotypes at the Regional Spices Research Centre, BARI, Gazipur during *rabi* 2018-19 and 2019-20. Twenty-nine local and exotic short-day onions were evaluated including two local checks BARI Piaz-1 and BARI Piaz-4. δ^2p and PCV was higher than δ^2g and GCV in almost all the traits studied and higher heritability (h^2b) was observed for total bulb yield. Significant variations were found in morphological and physiological traits for bulb production. Considerably higher bulb length and diameter were found from Ac_G_18_379, Ac_B_18_413, Ac_B_18_420, Ac_B_18_428, BARI Piaz-4, Ac_B_18_419 and Ac_B_18_417. Minimum bulb splitting (%) and bolting (%) were obtained from the genotypes Ac_G_18_379, Ac_G_18_381, Ac_B_18_413 and BARI Piaz-4. Higher dry matter content was noted for the genotypes BARI Piaz-4 (17.9 %), Ac_B_18_425 (21.73 %) and Ac_G_18_384 (21.57 %) along with the TSS ranged from 10.5 to 17.78^{0}Brix. The maximum bulb yield was obtained from the genotype Ac_B_18_413 (20.69 t/ha), followed by Ac_G_18_383 (20.6 t/ha), Ac_B_18_419 (18.48 t/ha) and Ac_B_18_417 (18.2 t/ha). These genotypes could be recommended for commercial cultivation as well as to use in future onion breeding program.

Keywords: Bulb weight, Bulb yield, Short day onion genotypes, TSS

Introduction

Onion (*Allium cepa L.*) is an herbaceous vegetable crop belongs to the family Amaryllidaceous (Alliaceae) which is originated in Iran, western Pakistan and Central Asia (Brewster, 2008) and is widely grown round the globe. Nutritionally it is rich in vitamins, minerals and some soluble sugars (Baliyan, 2014) while also having antioxidant

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and anti-cancerous properties designates as a medicinal crop. Onions are characterized by day length; "long-day" onion varieties will quit forming tops and begin to form bulbs when the day length reaches 14 to 16 hours while "short-day" onions will start making bulbs much earlier in the year when there are only 10 to 12 hours of daylight (Costa *et al.*, 2000). Although it is popular as a vegetable, onion is mostly used as a spice and it is a basic ingredient in Bangladeshi cuisine. Globally onion is grown over 5.4 million hectares with the production over 104.50 million tons annually, where India (26%) and China (23%) account for about half of the world's total onion production (FAO, 2020). Onion ranked first among the spices in Bangladesh, and has been cultivated in 185 thousand hectares of land and the production is 19.54 lakh metric tons (BBS, 2021). Daily per capita onion consumption was 22 grams in 2010, which has increased to 31.04 grams in 2016 (BBS, 2019) indicates an estimated 1.5g increased consumption annually. Every year Bangladesh has to import onion from abroad to fulfill her ever-growing demand. Most of the superior exotic onion genotypes or cultivars are long day (Requiring day length more than 14 hours) which needs longer growing periods for bulb formation and production of larger bulbs. If planted with these high yielding long day varieties in our short-day condition which resembles our winter season, doesn't suit well and generally form only top shoot but bulb formation inhibited which ultimately ends with small sized bulb. Exotic short-day onion genotypes or cultivars (bulb acquiring day length less than 14 hours) can be suited to our climatic condition and form bulbs. The existing available short-day varieties of our country have limited yielding potential much lower than the world average (19.35 t/ha) as well as neighboring countries production, and are not sufficient to fulfill targeted demand. Variability in onion is very scanty in our country. So, introduction of new genetic resources, studying their field level performance, testing the potential to acclimatize in our environmental condition, to select suitable genotype and to recommend for end user level cultivation could be a good strategy to improve the gross onion production. Considering the factors, the present study was undertaken to evaluate some local and exotic short-day onion genotypes along with existing checks for crop improvement and consequently make the suitable potential genotypes available for mass production.

Materials and Methods

A field experiment was carried out at the research station of Regional Spices Research Center, Bangladesh Agricultural Research Institute (BARI), Gazipur, during *rabi* 2018-19 and 2019-20 under irrigated conditions in clay loam soil having soil pH 5.78, organic matter 0.62 %, total N % 0.058 and available P 6.28 µg g^{-1}. A total of twenty-nine short day onion cultivars from different source (local and exotic) were evaluated including two local checks BARI Piaz-1 and BARI Piaz-4 for yield performance (Table 1). The treatments were arranged in randomized complete block design (RCBD) with two replications. Seeds were sown in seedbeds on 1st of November in 2018 and 30th October in 2019 and grown in the seedbeds for 45 days. Day length requirement of the studied genotypes were recorded during growing periods of 2018-19 and 2019-20 and are presented in figure-1. Seedlings were transplanted to the main field at 45 days. The plot size was 3m x 1.2 m and spacing maintained from row to row and plant to plant as 15 cm and 10 cm, respectively. Fertilization was done following

recommended dose of cow dung 5t/ha, $N_{115}P_{54}K_{75}S_{20}Zn_3B_2$ Kg/ha (FRG, 2018). The entire quantity of cow dung, P, S, Zn, B and one third of K were applied at the time of final land preparation and the rest K and urea were applied at 25, 50, and 75 days after planting. Irrigation was applied every 15 days interval, and was discontinued 3 weeks before the harvesting. The fungicide (Rovral @ 2.5 g/l) was sprayed at 15 days' interval starting from 45 days after transplanting. The insecticide Admire (Imidacloprid 70 WG) was applied to control thrips. Different onion genotypes were harvested separately on 24 March 2019 and on 28 March 2020 in the respective years. Ten plants from the middle rows were taken for sampling and data recording. Data were recorded on plant height (cm), number of leaves per plants (no.), bulb length (mm), bulb diameter (mm, bulb neck thickness (mm), individual bulb weight (IBW) (g), bulb splitting (%), bolting (%), days to maturity (days), dry matter content of bulbs (%), total soluble solid (TSS) (%) and total bulb yield (t/ha). Whole plot bulb yield was converted into total bulb yield per hectare. Data were analyzed using R platform (R Core Team, 2019).

Table 1. Bulb shape and color of 29 short-day onion genotypes collected from different sources

Entry No.	Name of Collection	Source of collection	Bulb shape	Bulb color
1	Ac_B_18_409	IARI, India	Rhomboid	Light Brown
2	Ac_B_18_410	MPUAT, Udaipur, Rajasthan, India	Flat globe	Light Brown
3	Ac_B_18_411	CCS, HAU, Hisar, India	Globe	Light Brown
4	Ac_B_18_412	ICAR-IIHR, Bangaluru, India	Broad elliptic	Red
5	Ac_B_18_413	IARI, India	Globe	Light Brown
6	Ac_B_18_414	ICAR-IARI, India	Rhomboid	Light Red
7	Ac_B_18_415	MPKVP, Rahuri, Maharashtra, India	Rhomboid	Light Brown
8	Ac_B_18_417	IARI, India	Rhomboid	Light Red
9	Ac_B_18_419	May be MP, India or Chennai	Flat globe	Light Brown
10	Ac_B_18_420	PAU, Ludhiana, Panjab, India	Globe	Light Brown
11	Ac_B_18_421	NHRDF, Nashik, India	Flat globe	Light Brown
12	Ac_B_18_422	ICAR-IARI	Flat globe	Light Brown
13	Ac_B_18_424	ICAR-IIHR, Bangaluru, India	Flat globe	Light Brown
14	Ac_B_18_425	NHRDF, Nashik, India	Flat globe	Light Brown
15	Ac_B_18_426	ICAR-IARI, India	Flat globe	Light Brown
16	Ac_B_18_427	PAU, Ludhiana, Panjab, India	Ovate	Light Red
17	Ac_B_18_428	NHRDF, Nashik, India	Flat globe	Light Brown
18	Ac_B_18_429	IIHR, Bangaluru, India	Ovate	Light Brown
19	Ac_B_18_430	ICAR-IARI, New Delhi, India	Flat globe	Light Brown

Table 1. Contd.

Entry No.	Name of Collection	Source of collection	Bulb shape	Bulb color
20	Ac_B_18_431	IIHR, Bangaluru, India	Flat globe	Red
21	Ac_B_18_433	ICAR-IIHR, Bangaluru, India	Globe	Red
22	Ac_G_18_379	Bangladesh	Flat globe	Red
23	Ac_G_18_380	Bangladesh	Ovate	Light Brown
24	Ac_G_18_381	NHRDF, India	Ovate	Light Brown
25	Ac_G_18_382	Bangladesh	Ovate	Light Brown
26	Ac_G_18_383	NHRDF, India	Globe	Light Red
27	Ac_G_18_384	Bangladesh	Flat globe	Light Brown
28	BARI Piaz-1	Regional Spices Research Centre, BARI, Gazipur	Flat globe	Light Brown
29	BARI Piaz-4	Regional Spices Research Centre, BARI, Gazipur	Globe	Red

*Color and shapes of bulbs were recorded following the descriptors for *Allium spp*, IPGRI, 2001

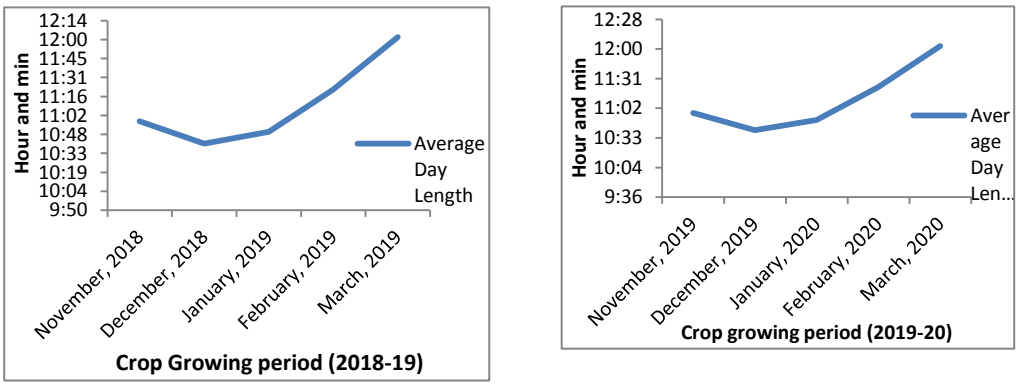

Fig. 1. Average day length of two cropping seasons during *rabi* 2018-19 and 2019-20

Results and Discussion

The analysis of variance for different characters is presented in Table 2 which indicated that there were highly significant differences among the genotypes for almost all of the characters studied except plant height and Total soluble solid (TSS). the variability estimates were presented in Table 3. The genotypic variance revealed that there were significant differences in almost all the characters. Similarly, year × genotype was significant for almost all the characters except for number of leaf and total soluble solute (TSS) indicating greater diversity in the genotypes of the traits but fluctuated over the growing seasons. Multi-environment or multi-year trials are prone to high levels of genotype-environment interaction due to differences in soil types, weather (precipitation,

temperature, radiation, evaporation, etc.), and management (fertility levels and levels of protection against pest and diseases) factors (Sangam *et al.,* 2020). In regards to the onion morphological traits, bulb characteristics, and bulb physical and physiological characteristics of the evaluated genotypes showed significant variation which were shown in Table 2.

Genetic variability among genotypes

The variability among the tested genotypes for the target traits allowed for the selection of desirable genotypes for future crop improvement. In the current study, the difference among the genotypes in response to twelve traits over two years were explained, and the results are shown in table 3. It was noted that the highest plant height was obtained in 2019-20 (51.73 cm). No of leaves per plant, days to maturity and bulb length showed almost similar values over two consecutive years. Considering bulb diameter, the maximum value was recorded in 2019-20 (37.83). Considering bulb neck thickness, Bulb Splitting, Bolting, Individual bulb weight, Bulb dry matter content, Total soluble solid and Total bulb yield showed almost similar values over the consecutive two years. The expression of every trait depends on the interaction between genes and environmental factors. Sometimes, more environmental influences hinder the expression of the traits. The variance due to genotype and phenotype indicate the contribution of the heritable part within a trait based phenotypic expression. In the present study the phenotypic variance appeared to be higher than the genotypic variance for all the traits over the years for all the genotypes (Table 3). However, the degree of genetic trait expression depends on the interaction of genotype with environment and farming practices. Previous research results of (Sekara *et al.*, 2017) also agree with the findings of the present study.

In this present investigation, the PCV was comparatively higher than the GCV for all traits, but the closer PCV and GCV for almost all traits over the consecutive two years, indicating the low impact of the environment on the expression of the traits, a symptom of the heritable nature of the traits.

Heritability is a tool that is used to estimate the degree of variation in a group population. The heritability in a group of the population can be classified into three groups (i.e., >80% is high, 40-80% is medium, and low is <40%). In the present investigation over two years' medium to high heritability was observed for almost all the traits.

Plant morphology and bulb characteristics

The mean performance of the genotypes did not vary significantly for plant height (Table 2 & 6). The highest plant height was recorded from Ac_B_18_415 (54.65 cm) which was followed by Ac_B_18_420 (53.63cm), Ac_G_18_382 (53.0 cm), Ac_B_18_419 (52.18 cm) and BARI Piaz-1 (52.50 cm), Whereas the lowest plant height was recorded from Ac_B_18_430 (43.18 cm) which was followed by BARI Piaz-4 (43.75 cm) and Ac_B_18_431 (44.20 cm) (Table 4 & 6). Ibrahim, (2010) as well as Trivedi and Dhumal, (2010) also observed differences in plant height amongst onion genotypes.

Table 2. Full joint combined analysis of variance for bulb yield and desirable traits in onion evaluated at Gazipur during *rabi* 2018-19 and 2019-20

Source of Variation	DF	MSS											
		Plant height (cm)	Number of leaves	Days to maturity	Bulb length (mm)	Bulb diameter (mm)	Bulb neck thickness (mm)	Bulb Spliting	Bolting	Individual bulb weight	Bulb dry matter content	Total soluble solid	Total bulb yield
Year	1	644.38**	3.80**	63.75**	113.33**	1136.32**	9.08**	3.42	5.27	111.05	132.62**	1.53	11.72
Genotype	28	33.96	0.39*	28.57**	39.92**	23.87**	2.63**	304.56**	28.87**	80.2**	21.38**	11.70	58.38**
Year × Genotype	28	37.27*	0.24	27.58**	14.60**	23.91**	2.015**	6.35	32.29**	65.19*	32.54**	10.7	86.48**
Error	56	21.65	0.21	6.68	4.68	7.06	0.76	4.10	12.93	38.42	9.178	7.70	4.06

DF= Degrees of freedom, MSS= Mean sum of square
* and ** indicates significant at 5% and 1% levels.

Table 3. Estimation of genetic parameters in twelve traits of 29 onion genotypes grown in 2018-2019 and 2019-20

Statistics	Plant height (cm)	Number of leaves	Days to maturity	Bulb length (mm)	Bulb diameter (mm)	Bulb neck thickness (mm)	Bulb Spliting (%)	Bolting (%)	Individual bulb weight (g)	Bulb dry matter content (%)	Total soluble solid (%)	Total bulb yield (t/ha)
2018-2019												
x□	47.01	5.96	146.76	29.70	31.57	9.67	9.60	4.66	34.42	19.13	13.40	12.73
h^2b	0.74	0.00	0.97	0.72	0.63	0.42	0.97	0.91	0.93	0.97	0.73	0.92
δ^2g	8.53	0.00	17.04	7.55	6.07	0.22	71.71	17.82	40.42	14.55	3.19	11.60
δ^2p	14.50	0.34	18.02	13.35	13.10	0.83	75.82	21.25	46.26	15.55	5.52	13.72
GCV	6.21	0	2.812	9.25	7.80	4.89	88.18	90.61	18.47	19.94	13.33	26.75
PCV	8.09	9.85	2.89	12.30	11.46	9.45	90.67	98.97	19.76	20.61	17.53	29.09
GA	5.80	0	8.49	5.44	4.72	0.79	17.44	8.66	13.07	7.85	3.55	6.99
Genetic gain	0.12	0	0.06	0.18	0.15	0.08	0	1.86	0.38	0.41	0.26	0.55
2019-2020												
X	51.73	5.59	148.24	31.67	37.83	9.11	9.26	4.23	36.75	16.99	13.63	13.36
h^2b	0.23	0.79	0.41	0.89	0.75	0.75	0.97	0.00	0.707	0.27	0.04	0.86
δ^2g	5.44	0.16	4.35	15.02	10.76	1.34	79.65	0.00	33.678	3.23	0.30	17.85
δ^2p	42.76	0.24	16.74	18.60	17.86	2.25	83.74	22.44	61.46	20.59	13.39	23.86
GCV	4.51	7.08	1.41	12.24	8.67	12.69	96.38	0.00	15.79	10.59	4.03	31.604
PCV	12.64	8.76	2.76	13.62	11.17	16.47	98.83	111.96	21.33	26.713	26.85	36.536
GA	3.04	0.798	3.48	7.94	6.55	2.30	18.38	0.00	11.43	2.58	0.331	8.61
Genetic gain	0.06	0.14	0.02	0.25	0.17	0.25	1.99	0.00	0.31	0.15	0.02	0.644

X: Grand Mean, LSD: Least Significant Difference, CV%: Coefficient of variation, h^2: Heritability, δ^2g: Genotypic variance, δ^2p: Phenotypic variance, GCV: genotypic coefficient of variation, PCV: Phenotypic coefficient of variation, GA: Genetic gain

Combined statistics of two years' consecutive study on number of leaves per plant showed significantly different pattern (Table 2 & 6). The number of leaves per plant ranged from 5.28 to 6.58. The results are in agreement with the reports of Boukary, *et al.,* (2012) and Dwivedi, *et al.,* (2012). Ijoyah, *et al*., (2008) observed that the number of leaves per plant in onion is controlled by genetic factors as well as by the environmental factor.

The number of days to maturity is very important as it determines the earliness or lateness of the bulb crop. Marked differences were observed for days to maturity among the genotypes (Table 2). When 80 % of the plant population showed neck fall symptom, we consider that as maturity. Combined analysis (Table 6) Showed that the genotype Ac_G_18_382 (152.25 days) took the maximum days to mature which was followed by Ac_B_18_412 (151.75 days), Ac_B_18_415 (151.75 days), Ac_B_18_420 (151.50 days), Ac_B_18_409 (151.50 days), and Ac_B_18_427 (150.75 days). On the contrary minimum days to maturity were observed in Ac_B_18_425 (142.75 days) which was closely followed by BARI Piaz-4 (143.25 days), Ac_B_18_426 (144.0 days) and BARI Piaz-1 (144.50 days). Days to maturity of onion bulb is influenced by environmental conditions like photoperiod and temperature. Earliness in onions depends on their capacity to initiate bulb formation in a reduced photoperiod and to develop the bulb rapidly after the critical photoperiod is reached. Provided photoperiod and temperature conditions above the critical point, the onion cycle is greatly reduced (Austin 1972).

The bulb length determines the size and shape of onion creating diversity which is very helpful for selecting desirable genotypes. The bulb length varied significantly due to different onion genotypes (Table 3). The highest bulb length was recorded in Ac_B_18_413 (40.0 mm) which was followed by BARI Piaz-4 (39.28 mm), Ac_B_18_419 (34.2 mm) and Ac_G_18_379 (33.18 mm). On the other hand, the genotype Ac_B_18_430 (25.67 mm) produced the lowest bulb length. The findings are agreed with the result obtained by Ishwori *et al.,* (2016), who observed that onion bulbs with high vertical bulb diameter can be stored longer than those with low vertical bulb diameter. The length of the onion bulb is dependent upon the number and size of the green leaves or tops at the time of bulb maturity.

Noticeable variation was observed in bulb diameter in respect of the genotypes (Table 3). Bulb diameter attributes to the size and shape of onion. The genotype Ac_B_18_413 (39.2 mm) produced the highest bulb diameter which was followed by Ac_B_18_420 (38.1 mm), Ac_B_18_417 (37.3 mm) Ac_B_18_433 (37.1 mm), Ac_B_18_428 (37.09 mm) and Ac_B_18_421(37.0 mm). On the contrary, the lowest bulb diameter was recorded in Ac_G_18_380 (27.5 mm). Morozowska, and Holubowicz. (2009) found that diameter of the bulb depends on ring of onion formed by the leaf.

The bulb neck thickness determines the longevity of the stored onion and lesser the thickness is better. The bulb neck thickness ranged from 7.97-11.47 mm (Table 3). The highest neck thickness was recorded in Ac_B_18_420 (11.47 mm) which was followed by Ac_B_18_419 (10.95 mm), Ac_B_18_422 (10.47 mm), Ac_B_18_417 (10.45 mm) and Ac_B_18_424 (10.35 mm). Whereas the lowest neck thickness was recorded in Ac_G_18_380 (7.97 mm). Hirave *et al.,* (2015) reported that, onion bulb with narrow neck thickness stored longer than those with wide collar diameter. The bulb neck thickness is believed to influence the storability of onion.

Table 4. Performances of onion genotypes on plant morphology and bulb characteristics at Gazipur during rabi 2018-19 and 2019-20

Genotype	Plant height (cm)		Number of leaves		Days to maturity		Bulb length (mm)		Bulb diameter (mm)		Bulb neck thickness (mm)	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Ac_G_18_379	49.65	51.20	5.65	5.70	145.00	148.00	37.15	29.21	37.75	35.15	11.36	7.80
Ac_G_18_380	46.00	51.30	6.15	5.40	149.00	142.50	31.00	28.92	24.30	30.75	8.23	7.70
Ac_G_18_381	53.35	49.60	5.80	5.10	149.00	142.50	29.95	34.89	22.90	38.38	7.72	8.70
Ac_G_18_382	51.20	54.80	6.00	6.20	157.00	147.50	32.25	29.10	30.80	34.95	9.76	8.80
Ac_G_18_383	50.85	51.50	6.15	6.00	150.50	146.50	30.70	32.07	28.30	40.60	9.49	7.00
Ac_G_18_384	45.85	51.00	5.50	6.20	142.50	148.50	28.50	24.95	33.40	32.90	9.65	8.10
Ac_B_18_409	45.50	50.80	6.20	5.10	152.50	150.50	28.40	33.08	30.30	41.75	9.06	9.10
Ac_B_18_410	43.15	57.60	5.35	5.20	145.50	149.00	27.70	33.93	31.00	39.80	9.87	7.30
Ac_B_18_411	47.50	48.80	5.70	5.90	148.50	148.00	30.45	28.88	34.40	36.56	9.76	9.50
Ac_B_18_412	48.30	49.20	6.00	5.10	149.50	154.00	28.30	32.12	29.65	43.90	10.02	8.60
Ac_B_18_413	45.85	54.00	6.00	5.30	142.00	148.50	35.45	44.58	35.55	42.89	10.53	7.90
Ac_B_18_414	48.35	47.10	5.85	5.20	149.50	146.00	28.00	29.17	30.60	38.93	9.50	7.90
Ac_B_18_415	48.20	61.10	6.50	5.60	148.50	155.00	26.20	31.70	29.90	35.90	9.11	10.60
Ac_B_18_417	50.85	52.80	6.20	5.50	146.00	145.50	30.65	31.58	34.00	40.68	10.79	10.10
Ac_B_18_419	44.15	60.20	6.35	6.80	149.50	148.00	31.70	36.73	31.25	41.50	10.30	11.60
Ac_B_18_420	48.35	58.90	6.65	5.40	149.50	153.50	29.80	32.85	34.80	41.45	10.45	12.50
Ac_B_18_421	43.50	46.40	6.30	6.20	142.50	150.50	29.20	33.13	34.00	40.00	9.87	8.20
Ac_B_18_422	43.50	50.60	6.35	6.10	141.50	149.00	28.15	28.80	32.55	33.93	10.14	10.80
Ac_B_18_424	44.15	57.60	5.35	5.60	147.50	145.50	27.05	32.25	32.25	35.91	10.00	10.70
Ac_B_18_425	42.00	54.90	6.35	6.30	141.50	144.00	23.80	29.38	29.45	38.71	8.89	9.20
Ac_B_18_426	47.15	49.30	5.50	5.40	142.50	145.50	27.35	30.47	31.15	37.65	9.09	10.20

Table 4. Contd.

Genotype	Plant height (cm)		Number of leaves		Days to maturity		Bulb length (mm)		Bulb diameter (mm)		Bulb neck thickness (mm)	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Ac_B_18_427	45.70	56.60	6.00	5.60	153.50	148.00	28.55	32.77	28.90	35.89	9.17	8.50
Ac_B_18_428	44.65	51.80	5.65	5.60	148.50	147.50	30.15	34.91	30.10	44.08	9.66	9.60
Ac_B_18_429	49.00	48.60	6.00	5.30	146.50	151.50	30.40	31.42	32.30	34.70	9.94	7.90
Ac_B_18_430	46.85	39.50	6.15	5.20	143.50	154.00	28.00	23.35	33.20	29.56	9.43	7.70
Ac_B_18_431	39.20	49.20	5.85	5.40	141.50	150.50	27.60	28.17	33.20	37.10	10.06	9.10
Ac_B_18_433	51.30	52.50	6.00	5.00	149.50	147.50	27.65	33.15	31.70	42.50	9.32	10.40
BARI Piaz-1	53.50	51.50	5.70	5.50	144.00	145.00	27.58	28.04	33.83	35.95	9.31	9.50
BARI Piaz-4	45.80	41.70	5.45	5.30	139.50	147.00	39.55	39.02	33.92	34.94	10.00	9.20
Levlel of significance	**	ns	ns	**	**	ns	**	**	**	**	ns	**
$LSD_{0.05}$	5.01	-	-	0.59	2.03	-	4.93	3.88	5.43	5.46	-	1.96
CV	5.20	11.81	9.85	5.17	0.68	2.37	8.11	5.97	8.40	7.04	8.08	10.49

** 1% level of probability, ns: non-significant LSD: Least Significant Difference, CV%: Coefficient of variation

Table 5. Performances of onion genotypes on physical, physiological and bulb yield at Gazipur during rabi 2018-19 and 2019-20

Genotype	Bulb splitting (%)		Bolting (%)		Individual Bulb Weight (g)		Bulb dry matter content (%)		TSS^0 Brix		Total bulb Yield (T/ha)	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Ac_G_18_379	0.00	0.00	0.00	8.85	29.05	33.22	25.46	12.40	12.78	10.70	16.10	12.67
Ac_G_18_380	4.47	3.90	19.34	0.00	26.55	31.35	16.39	22.16	12.43	15.95	7.61	9.67
Ac_G_18_381	0.00	0.00	0.00	0.00	29.24	32.45	16.01	18.03	11.34	16.70	9.77	17.00
Ac_G_18_382	6.39	2.68	1.19	13.83	37.72	30.58	13.49	23.74	11.35	12.95	10.08	14.00
Ac_G_18_383	2.00	1.32	11.14	6.49	44.10	51.8	15.93	21.46	10.30	12.70	19.45	21.67
Ac_G_18_384	16.47	14.97	0.74	1.08	35.00	27.83	23.76	19.39	15.98	14.30	12.23	9.67
Ac_B_18_409	3.32	4.17	7.50	11.80	37.25	40.86	20.97	15.71	10.63	14.50	9.70	11.77
Ac_B_18_410	4.45	4.50	5.15	6.35	31.50	27.89	15.86	19.08	11.25	15.50	11.22	11.00
Ac_B_18_411	9.16	6.61	12.24	0.87	40.05	30.14	18.71	14.28	13.63	14.70	10.98	12.67
Ac_B_18_412	7.02	3.49	4.20	1.60	40.09	43.23	18.95	12.53	10.90	10.20	13.57	16.85
Ac_B_18_413	0.00	0.00	2.38	2.47	45.50	39.16	27.09	15.83	12.88	9.95	19.39	22.00
Ac_B_18_414	4.45	5.64	3.05	3.52	29.95	27.34	17.96	16.08	15.18	14.95	7.13	10.00
Ac_B_18_415	8.44	5.82	7.35	7.58	38.35	44.88	17.71	14.60	11.33	11.90	15.17	18.00
Ac_B_18_417	12.26	16.33	6.44	3.80	39.35	40.42	12.70	13.77	14.70	15.00	17.08	19.33
Ac_B_18_419	10.16	7.10	3.51	2.44	40.60	38.55	16.32	18.28	12.33	15.45	17.63	19.33
Ac_B_18_420	6.50	1.89	2.44	4.22	41.95	42.35	16.43	18.43	11.38	10.05	9.85	11.67
Ac_B_18_421	19.06	19.03	4.69	6.76	27.50	43.34	25.13	14.80	15.70	10.52	11.74	8.00
Ac_B_18_422	21.02	23.73	0.00	2.55	29.15	29.37	18.86	13.81	16.43	13.90	12.39	7.00
Ac_B_18_424	4.06	4.59	5.94	3.85	33.90	32.89	20.58	16.98	12.78	19.50	13.05	14.33
Ac_B_18_425	20.72	23.51	0.00	2.14	22.85	26.53	19.02	24.45	16.30	19.25	8.54	6.70
Ac_B_18_426	14.12	15.19	1.86	4.78	25.60	27.67	20.13	17.32	14.45	14.80	12.46	9.00
Ac_B_18_427	4.46	1.47	3.30	1.25	36.75	39.87	20.93	14.64	12.85	15.25	11.62	14.33

Table 5. Contd.

Genotype	Bulb splitting (%)		Bolting (%)		Individual Bulb Weight (g)		Bulb dry matter content (%)		TSS^0 Brix		Total bulb Yield (T/ha)	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Ac_B_18_428	5.92	5.22	6.09	0.75	38.05	33.11	14.99	19.21	11.10	14.70	15.26	17.33
Ac_B_18_429	9.49	13.28	10.40	4.40	28.75	39.71	19.45	12.96	12.65	10.70	6.92	8.00
Ac_B_18_430	31.44	27.17	0.00	2.15	25.15	46.86	20.46	14.91	15.45	10.30	11.70	10.07
Ac_B_18_431	18.48	23.57	3.90	4.20	27.70	40.92	22.76	13.39	15.00	10.30	12.71	7.63
Ac_B_18_433	4.54	5.28	2.96	3.50	41.90	36.9	11.89	13.78	14.15	14.10	13.21	15.33
BARI Piaz-1	30.13	28.11	7.25	6.88	30.55	43.01	23.39	22.66	17.90	12.60	13.17	12.67
BARI Piaz-4	0.00	0.00	2.05	4.60	44.06	43.67	23.35	18.03	15.55	13.90	19.52	20.00
Levlel of significance	**	**	**	ns	**	**	**	ns	**	**	**	**
$LSD_{0.05}$	4.15	4.15	3.80	-	4.95	10.79	2.05	-	3.13	7.41	2.97	5.02
CV	21.10	21.87	19.80	11.96	7.02	14.34	5.22	24.53	11.39	26.54	11.42	18.33

** 1% level of probability LSD: Least Significant Difference, CV%: Coefficient of variation

Table 6. Performances of onion genotypes over the year on plant morphology and bulb characteristics at Gazipur during rabi 2018-19 and 2019-20

Genotype	Plant height (cm)	Number of leaves	Days to maturity	Bulb length (mm)	Bulb diameter (mm)	Bulb neck thickness (mm)
Ac_G_18_379	50.43	5.68	146.50	33.18	36.45	9.58
Ac_G_18_380	48.65	5.78	145.75	29.96	27.52	7.97
Ac_G_18_381	51.48	5.45	145.75	32.42	30.64	8.21
Ac_G_18_382	53.00	6.10	152.25	30.68	32.88	9.28
Ac_G_18_383	51.18	6.08	148.50	31.38	34.45	8.25
Ac_G_18_384	48.43	5.85	145.50	26.73	33.15	8.88
Ac_B_18_411	48.15	5.80	148.25	29.66	35.48	9.63
Ac_B_18_430	43.18	5.68	148.75	25.67	31.38	8.56
Ac_B_18_412	48.75	5.55	151.75	30.21	36.78	9.31
Ac_B_18_420	53.63	6.03	151.50	31.32	38.13	11.47
Ac_B_18_415	54.65	6.05	151.75	28.95	32.90	9.86
Ac_B_18_425	48.45	6.33	142.75	26.59	34.08	9.05
Ac_B_18_424	50.88	5.48	146.50	29.65	34.08	10.35
Ac_B_18_410	50.38	5.28	147.25	30.81	35.40	8.59
Ac_B_18_409	48.15	5.65	151.50	30.74	36.03	9.08
Ac_B_18_428	48.23	5.63	148.00	32.53	37.09	9.63
Ac_B_18_422	47.05	6.23	145.25	28.48	33.24	10.47
Ac_B_18_413	49.93	5.65	145.25	40.01	39.22	9.21
Ac_B_18_431	44.20	5.63	146.00	27.89	35.15	9.58
Ac_B_18_419	52.18	6.58	148.75	34.22	36.38	10.95
Ac_B_18_427	51.15	5.80	150.75	30.66	32.39	8.84
Ac_B_18_421	44.95	6.25	146.50	31.17	37.00	9.04
Ac_B_18_429	48.80	5.65	149.00	30.91	33.50	8.92
Ac_B_18_414	47.73	5.53	147.75	28.59	34.77	8.70
Ac_B_18_417	51.83	5.85	145.75	31.12	37.34	10.45
Ac_B_18_426	48.23	5.45	144.00	28.91	34.40	9.65
Ac_B_18_433	51.90	5.50	148.50	30.40	37.10	9.86
BARI Piaz-1	52.50	5.60	144.50	27.81	34.89	9.41
BARI Piaz-4	43.75	5.38	143.25	39.28	34.43	9.60
$LSD_{0.05}$	6.59	0.66	3.66	3.07	3.76	1.24
CV	9.42	8.01	1.75	7.06	7.66	9.30

LSD= Least significant difference, CV= Co-efficient of variation

Table 7. Performances of onion genotypes over the year on plant physical, physiological and bulb yield at Gazipur during rabi 2018-19 and 2019-20

Genotype	Bulb splitting (%)	Bolting (%)	Individual Bulb Weight (g)	Bulb dry matter content (%)	TSS^0 Brix	Total bulb Yield (t/ha)
Ac_G_18_379	0.00	4.43	31.14	18.93	11.74	14.38
Ac_G_18_380	4.18	9.67	28.95	19.27	14.19	8.64
Ac_G_18_381	0.00	0.00	30.84	17.02	14.02	13.39
Ac_G_18_382	4.53	7.51	34.15	18.61	12.15	12.04
Ac_G_18_383	1.66	8.81	42.95	18.69	11.50	20.56
Ac_G_18_384	15.72	0.91	31.42	21.57	15.14	10.95
Ac_B_18_411	7.88	6.56	35.10	16.49	14.16	11.82
Ac_B_18_430	29.30	1.08	36.01	17.68	12.88	10.89
Ac_B_18_412	5.26	2.90	41.66	15.74	10.55	15.21
Ac_B_18_420	4.20	3.33	42.15	17.43	10.71	10.76
Ac_B_18_415	7.13	7.47	41.62	16.15	11.61	16.59
Ac_B_18_425	22.11	1.07	29.19	21.73	17.78	7.62
Ac_B_18_424	4.32	4.89	33.40	18.78	16.14	13.69
Ac_B_18_410	4.48	5.75	32.20	17.47	13.38	11.11
Ac_B_18_409	3.75	9.65	36.56	18.34	12.56	10.73
Ac_B_18_428	5.57	3.42	35.58	17.10	12.90	16.30
Ac_B_18_422	22.38	1.28	29.26	16.33	15.16	9.69
Ac_B_18_413	0.00	2.43	42.33	21.46	11.41	20.69
Ac_B_18_431	21.03	4.05	34.31	18.07	12.65	10.17
Ac_B_18_419	8.63	2.97	37.08	17.30	13.89	18.48
Ac_B_18_427	2.97	2.28	35.81	17.78	14.05	12.98
Ac_B_18_421	19.04	5.73	35.42	19.96	13.11	9.87
Ac_B_18_429	11.38	7.40	34.23	16.20	11.68	7.46
Ac_B_18_414	5.05	3.29	31.15	17.02	15.06	8.56
Ac_B_18_417	14.29	5.12	37.39	13.23	14.85	18.20
Ac_B_18_426	14.66	3.32	29.14	18.72	14.63	10.73
Ac_B_18_433	4.91	3.23	36.90	12.83	14.13	14.27
BARI Piaz-1	29.12	7.06	36.78	23.02	15.25	12.92
BARI Piaz-2	0.00	3.33	43.87	20.69	14.73	18.76
$LSD_{0.05}$	2.87	5.10	8.78	4.29	3.93	2.85
CV	21.48	28.93	17.51	16.78	20.54	15.44

LSD= Least significant difference, CV= Co-efficient of variation, TSS=Total soluble solid

Physical and physiological characteristics

Splitting of onion bulb greatly reduced the economic value of the crop as well as storability. The genotypes evaluated for bulb splitting (%) showed a great deal of

variation (Table 3 & 7). The genotype Ac_B_18_430 (29.3 %) showed highest bulb splitting which was followed by BARI Piaz-1 (29.1%), Ac_B_18_422 (22.38%), Ac_B_18_425 (22.1%) and Ac_B_18_431 (21.0 %). On the other hand, no bulb splitting was recorded from the genotype Ac_G_18_379, Ac_G_18_381, Ac_B_18_413 and BARI Piaz-4. Regarding genotypic effects on bulb splitting the results of the present study were partially in agreement with the report of Jilani and Abdul Ghaffor (2003), where they reported the onion genotypes varied significantly in number of split/double bulbs. The large size sets increased number of doublings, split and early bolting bulbs.

The mean bolting performance of twenty-nine onion genotypes is presented in table 7. Variability was found among the genotypes and it ranged from 0 to 9.67%. The genotype Ac_G_18_380 (9.67 %) and Ac_B_18_409 (9.65 %) showed the highest bolting which was followed by Ac_G_18_383 (8.8 %), Ac_G_18_382 (7.5 %) and Ac_B_18_415 (7.47 %). Whereas no bolting was recorded in Ac_G_18_381 and Ac_G_18_384. Though all the genotypes received the same fertilizer and cultural management, but varied in their performance to induce bolting. It is more of genotypes feature triggered from the input applied during growing stages. This result is consistent with previous reports indicating that genotype influences onion bolting (Rabinowitch, 1990).

A great deal of genotypic variation was observed in case of individual bulb weight (Table 3 & 7). The mean performance of the onion genotypes showed that the highest Individual bulb weight was produced by the check BARI Piaz-4 (43.87 g) which was followed by Ac_G_18_383 (42.95g), Ac_B_18_413 (42.33 g), Ac_B_18_420 (42.15g), Ac_B_18_412 (41.66 g) and Ac_B_18_415 (41.6 g). The lowest individual bulb weight was recorded from Ac_G_18_380 (28.95 g). Clear sunshine and no foggy weather during vegetative growing period and dry weather and no rain at maturity period favors high photosynthetic rate and higher bulb yield. The maximum individual bulb weight may be due to genotypic character, photosynthetic activity and nutrient availability to the plant, which directly influence on the bulb yield. The variation in individual bulb weight among different genotype might be due to genetic characters of the genotypes. The results were similar to Lakshmipathi (2016) and Suhas (2016), where they found different individual bulb weight from different genotypes.

The genotypes exhibited a wide range of variability in respect of bulb dry matter content (table 3 &7). The maximum dry matter was recorded from the check BARI Piaz-1 (23.02 %) which was followed by Ac_B_18_425 (21.73 %), Ac_G_18_384 (21.57%) and Ac_B_18_413 (21.46 %). On the contrary the lowest dry matter content was recorded from Ac_B_18_433 (12.83 %) and Ac_B_18_417 (13.23%). Preliminary selection of genotypes for good storability based on high bulb dry matter content at harvest could be useful but bulb should be evaluated further after storage. Dry matter content is also believed to influence long storage period of bulb onion in India (Mahanthesh *et al.*, 2008) as well as in Nigeria (Kabura *et al.*, 2008). Genotypes with high dry matter have longer shelf-life and these types of genotypes are recommended for industrial processing.

The genotypes showed wide range of variability in respect of TSS (^{0}Brix) (Table 3 & 7). The maximum TSS (^{0}Brix) was recorded from Ac_B_18_425 (17.78^{0}Brix) which

was followed by Ac_B_18_424 (16.14^{0}Brix), BARI Piaz-1 (15.25^{0}Brix), Ac_B_18_422 (15.16^{0}Brix) and Ac_G_18_384 (15.1^{0}Brix). On the other hand, lowest TSS was recorded from Ac_B_18_412 (10.55^{0}Brix) which was followed by Ac_B_18_420 (10.71^{0}Brix). Preliminary selection of genotypes for good storability based on high TSS (^{0}Brix) at harvest could be useful, but bulb should be evaluated further after storage, as TSS level undergoes ups and downs depending upon the storage condition and duration (Sohany *et al*., 2016; Dabhi *et al.,* 2008).

Total bulb yield

The total bulb yield (t/ha) was greatly influenced by different onion genotypes and showed range of variability (Table 3 & 7). The total bulb yield ranged from 7.46-20.69 (t/ha). The maximum bulb yield was recorded from the genotype Ac_B_18_413 (20.69 t/ha) which was followed by the genotype Ac_G_18_383 (20.56 t/ha), BARI Piaz-4 (18.76 t/ha), Ac_B_18_419 (18.48 t/ha) and Ac_B_18_417(18.2 t/ha). However, the minimum total bulb yield was recorded from the genotype Ac_B_18_429 (7.46 t/ha) which was followed by Ac_B_18_425 (7.6 t/ha), and Ac_G_18_380 (8.6 t/ha). The bulb yield is a polygenic character greatly influenced by the genotype and environment interaction. The variation in the total bulb yield per plot could be attributed from weight and size of different onion genotypes which might be contributed towards the production of higher bulb yield per plot. Similar finding was also reported by Lakshmipathi (2016) and Suhas (2016).

Conclusion

The collection of short-day genotypes showed significant variation in terms of morphological and physiological traits. Improvement of onion yield contributing traits was possible using phenotypic selection for Bulb length, Bulb diameter, individual bulb weight, Bulb dry matter content, Total soluble solid and bulb yield, of which showed high value for genotypic and phenotypic coefficient of variation coupled with h^2b (Heritability) and GA (Genetic advance). Compared to the check varieties for above mentioned traits the genotypes Ac_B_18_409, Ac_B_18_413, Ac_B_18_417, Ac_B_18_420, Ac_G_18_383, Ac_B_18_412, Ac_B_18_424, Ac_B_18_415, Ac_G_18_379 and Ac_B_18_419 were promising. It is being suggested that these promising genotypes could be used in the breeding program for crop improvement.

Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this manuscript.

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