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ADAPTIVE PERFORMANCE OF GARLIC VARIETIES UNDER HIGH GANGES RIVER FLOODPLAIN SOIL (CALCAREOUS) OF BANGLADESH

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ABSTRACT. Any variety needs to evaluate at different locations, along with variable soils for asses their yield potentiality after its releasing. Thus, an experiment was conducted at Multi Location Testing (MLT) site, Kushtia Sadar Upazila, under High Ganges River Floodplain (AEZ-11) in Bangladesh, during three consecutive Rabi seasons of 2013-2014 to 2015-2016. The objective of this study was to evaluate the performances of garlic varieties and economic profitability of these varieties at farmer's field. There were three garlic varieties, namely BARI Rashun-1, BARI Rashun-2 and a local cultivar, which were evaluated at six dispersed locations as replications. Results observed that the highest yield (8.34-9.80 t ha^{-1}) was obtained from BARI Rashun-1, which was followed by BARI Rashun-2 (7.43-9.48 t ha^{-1}) and the local one (7.12-9.15 t ha^{-1}). BARI Rashun-1 produced 3-12% higher yield over BARI Rashun-2 and 7-20% over the local cultivar, respectively in three consecutive years. Correlation analysis showed that there were positive and significant correlation among bulb yields with bulb length and individual bulb weight. Regarding the functional relationship, the traits like crop duration, plant population, plant height, bulb length, bulb width, individual bulb weight had positive contribution on the bulb

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yield. It was dependent on those traits, and accounted for 12, 36, 0.05, 45, 41 and 55% of the total bulb yield variation, respectively. The highest gross return (Tk. 3, 63,700 ha^{-1}) and gross margin (Tk. 2,19,425 ha^{-1}) were obtained from BARI Rashun-1. As such, this variety performed as the best, in respect of higher bulb yield potential, as well as the highest economic return among the tested varieties, which was followed by BARI Rashun-2. Therefore, the result of this study could be helpful for improving bulb production of garlic under High Ganges River Floodplain soil (calcareous soils) in Bangladesh.

Keywords: *Allium sativum* L.; yield potentiality; functional relationship; economics efficiency; adaptation.

INTRODUCTION

Garlic (*Allium sativum* L.) is one of the most important aromatic herbaceous annual spices under the family *Alliaceae* (Kurian, 1995), which widely used in the Globe including Bangladesh. It is the second most widely used cultivated *Allium*, after onion (Bose and Som, 1990), with a characteristic of pungent smell. China is the largest garlic producing country in the world, amounting 21.20 million tons per annum, while Bangladesh produces about 3.12 lakh ton, ranking fourth in the world context (FAOSTAT, 2016). Garlic requires cold, but dry weather, with moderate moisture for proper growth. It also requires well drained soil, with high organic matter content. It is sensitive to high humidity, excessive moisture and high temperature, which limits the growth of the crop (Babaji, 1996). Garlic has been known to have several food and medicinal values. Garlic extracts are generally used in curing whooping cough, lung diseases and stomach pain and child birth disorder. The extract could be used against ear-ache, hypertension, eye-sores, an antidote against poisons and antibacterial agent, as well as reduced cholesterol level in human blood. It has been recognized, all over the world as a valuable spice for cooking different dishes. Garlic has higher nutritive value than other bulb crops, as it is rich in proteins, phosphorus, potassium, calcium, magnesium, and carbohydrates and hence also finds medicinal usage, especially in treating intestinal diseases (Rahman and Islam, 2016). It contains about 30-35% dry matter, 6-7% protein, 0.2% lipid and 23-28% carbohydrates (Khatun *et al.,* 2014).

In Bangladesh, during 2016-2017, the estimated area for garlic was about 66,289 hectares, which is 16.08% of total spices and condiments areas and its production was 4.25 lakh metric tons with average yielding of 6.42 tha^{-1} (BBS, 2018). But, the production is extremely insufficient in terms of demand and the average yield is quite low, compared to other garlic growing countries. This low yield may be due to the cultivation of the low yielding local varieties, incidence of diseases and insects, lack of technological knowledge of the growers etc. Spices Research Centre, Bangladesh Agricultural Research Institute (BARI) has developed four

garlic varieties, namely BARI Rashun-1, BARI Rashun-2, BARI Rashun-3 and BARI Rashun-4, which are high yielding varieties (yield potentiality 6-11 t ha^{-1}) and less susceptible to pests and diseases. These varieties expected to be promising in increasing generation of farmers' income in a very short period of time.

The yield potentiality of a variety depends on several factors especially in soil and environmental traits, likes temperature, rainfall and relative humidity. Not only is that variety/genotypes also responsible for yield potentiality (Islam *et al.,* 2015). As garlic cultivated in winter season it face water shortage due to negligible precipitation (Islam and Zaman, 2017). Hence, amount of rainfall, during the growing period, is responsible for yield variation of garlic. Climatic condition also varies one year to another. So, judgment of yield potentiality in a particular variety should be evaluated in several years. However, performance of garlic varieties has not yet been evaluated under different agro-climatic conditions, especially for calcareous soils in Bangladesh. Considering the above perspectives, the present study was conducted to find out the performances of garlic varieties and economic profitability at farm field, along with calcareous soils in three consecutive years.

MATERIALS AND METHODS

The experiment was carried out at Multi Location Testing (MLT) site of Kushtia Sadar (Latitude: 23.87736^0 N; Longitude: 89.09126^0 E) in Bangladesh, during Rabi season (October to April) of the consecutive three years (2013-2014 to 2015-2016), at farm field conditions. The land was medium high with flood free well drained. The altitude of the experimental site is 17 m and the maximum and minimum temperature ranged 22.9-38.2^{0}C and 8.5-23.4^{0}C, respectively, during the growing period of respective years (*Fig. 1*).

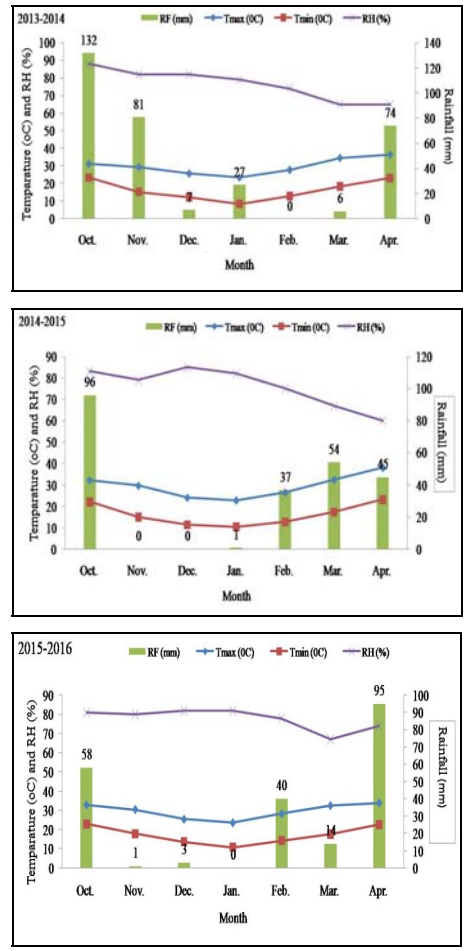

Figure 1 - Monthly climatic scenario during the growing period of garlic experiment (2013-2015)

Month wise weather parameter, *viz*., temperature (Tmax and Tmin), total rainfall (mm) and relative humidity (%), during the period of respective years (2013-2014 to 2015-2016) have been presented in *Fig. 1*. The soil is calcareous in nature, under High Ganges River Floodplain (AEZ-11). The initial soil chemical properties of the experimental soil have been depicted in *Table 1*.

Table 1 - Initial soil chemical properties of the experimental soil and their interpretation according to FRG (2012)

Items	pH	Organic matter (%)	K meq/100 g soil	Total N (%)	P	S	Zn	B
					μg g^{-1}			
Initial soil	7.93	2.02	0.26	0.10	10.40	19.00	0.82	0.47
Critical limit	-	-	0.12	0.12	10.00	10.00	0.60	0.20
Interpretation	Slightly alkaline	Medium	Medium	Low	Low	Medium	Low	Medium

The experiment was laid out in randomized completely block design, with six dispersed replications. The unit plot size was 6 m × 5 m. Three varieties of garlic, *viz.* BARI Rashun-1, BARI Rashun-2 and local were tested. The seeds (clove) were planted in 25 November - 8 December, 2013-2014; 06-13 December, 2014-2015 and 30 October to 18 November, 2015-2016, with spacing of 15 cm × 10 cm. The date of sowing varied due to raining before land preparation and different farm plot. The soil was fertilized with $N_{100}P_{54}K_{167}S_{20}B_{1.7}$kg ha^{-1} and cow dung 5 t ha^{-1} (Mondal *et al.,* 2011). The entire amount of cowdung, P, S, B and ½ of N and ½ of K were applied at the time of final land preparation. The remaining N and K were top dressed in equal two splits, at 25 and 50 days, after planting (DAP). The crops were weeded one time (20-25 days after clove emergence), while five times sprayed with Rovral, Antracol and Score for controlling purple blotch (*Alternaria porri*) and leaf burn (*Fusarium oxysporum*) diseases, as well as Tafgor 40 Ec, Admire and Vertimec were done to control thrips and mite. Irrigation was applied in four times at 15, 30, 45, and 60 days after planting (DAP). The crop was harvested on 21 March - 7 April, 2014, 1-9 April, 2015 and 10 March to 5 April, 2016. Data on different parameters like plant population, plant height, bulb length, bulb width, individual bulb wt. and bulb yield were recorded from 1 m^2 in three areas from each treatment plot. Then it was computed and analyzed statistically using Statistics R package. The analyzed data was adjusted with Least Significant Difference (LSD) test at 5% level. Per hectare gross return (GR), total cost (TC), total variable cost (TVC), gross margin (GM), net return (NR) and benefit cost ratio (BCR) were calculated on the basis of prevailing market price of the input and output.

GR = Return of main product = Yield × price (Tk.); TC = All input cost including rental value of land and interest on operating capital; TVC = All input cost except rental value of land; NR = GR - TC; GM = GR – TVC

$$\text{Benefit-Cost Ratio} = \frac{\text{Gross return}}{\text{Total cost}}$$

RESULTS AND DISCUSSION

Initial soil properties of the experimental soil

The soil analysis data revealed that all the nutrients were above the

critical limit, except total nitrogen (*Table 1*). Organic matter was medium (2.02%). The pH of the study soils is 7.93, indicated slightly alkaline. The texture of the soil was clay loam, with field capacity 28.5 to 29.3%. As a whole, the soil is moderately good for garlic crop.

Performance of yield contributing characters and bulb yield of garlic

Interaction in between studies varieties (V) and respective years (Y), there were significant variations observed among the study traits except plant population and plant height (*Table 2*). Results revealed that BARI Rashun-1 (V_1) gave the maximum value, in respect of all the study traits, followed by BARI Rashun-2 (V_2) and the local cultivar (V_3). Least value was observed in local cultivar among all the characters. Similarly, among the study years Y_1 (2013-2014) produced the highest average value of the respective traits, as compared to Y_2 (2014-2015) and Y_3 (2015-2016). However, crop duration ranged from 129-134 days, 125-126 days, and 118-120 days, respectively, in Y_1, Y_2 and Y_3. Likewise, plant population per meter squire ranged 46.32-47.95 (no.), 46.32-46.60 (no.) and 42.50-44.92 (no.); plant height ranged 54.00-68.67 (cm), 52.67-69.14 (cm) and 51.33-64.17 (cm); bulb length ranged 2.95-3.02 (cm), 2.57-2.82 (cm) and 1.95-2.43 (cm); bulb width ranged 2.94-2.98 (cm), 2.55-2.77 (cm) and 1.90-2.36 (cm); individual bulb weight ranged 17.49-19.14 (g), 15.96-17.18 (g) and 14.28-16.82 (g). It was noticed that V_1 and V_2 required 11-14 days and 6-7 days more crop duration than the local cultivar (V_3), and could easily be fitted in the existing farmers adorned cropping pattern (Garlic - Jute - T. aman).

Among the tested garlic varieties, the bulb yield varied significantly from each others (*Fig. 2*). However, BARI Rashun-1 gave the maximum bulb yield (8.92 t ha^{-1}), compared to BARI Rashun-2 (8.29 t ha^{-1}) and local cultivar (7.99 t ha^{-1}). Garlic is sensitive to water stress. Due to water stress garlic loses bulb yield of 60-70% (Islam *et al.,* 2012). Adequate supply of water during the growing period increased considerable amount bulb yield (Islam and Zaman, 2017). In the present study, bulb yield produced maximum (9.48 t ha^{-1}) in the year of Y_1 (*Fig. 3*). It might be due to this year received maximum seasonal rainfalls (121 mm), as compared to year 2014-2015 (92 mm) and 2015-2016 (58 mm), which responsible of higher yield.

Concerning the interaction of garlic variety and year, there was also a significant effect observed in respect of bulb yield of garlic (*Table 2*). Results seem that significantly highest bulb yield was obtained from BARI Rashun-1 with three consecutive years, as compared to other cultivars. On the contrary, year Y_1 was the top bulb yield producer than Y_2 and Y_3, in respect of all the varieties. BARI Rashun-1 produced 3, 8 and 12% higher bulb yield than BARI Rashun-2, while 7, 12 and 20% higher than the local

cultivar, respectively in Y_1, Y_2 and Y_3. Significantly higher bulb yield potential of BARI Rashun-1 variety might be attributed to higher plant height, bulb length, bulb width and individual bulb weight. Similar findings were reported by Mozumder *et al.* (2015). Islam *et. al.,* (2015) reported that the highest yield was recorded in BARI Rashun-2 and it was followed by BARI Rashun-1 and local.

Table 2 - Yield and yield contributing characters of garlic varieties under High Ganges River Floodplain soil (AEZ-11) in Kushtia District (pooled average of 2013-14, 2014-15 and 2015-16)

Inter actions	Crop duration (day)	Plant population (no. m^{-2})	Plant height (cm)	Bulb length (cm)	Bulb width (cm)	Individual bulb weight (g)	Bulb Yield (t ha^{-1})
$Y_1 \times V_1$	131.00	47.95	68.67	3.02	2.98	19.14	9.80
$Y_1 \times V_2$	124.67	46.55	66.70	2.82	2.77	17.18	9.48
$Y_1 \times V_3$	118.67	44.92	64.17	2.43	2.36	16.62	9.15
$Y_2 \times V_1$	129.57	46.32	54.00	2.97	2.94	18.67	8.61
$Y_2 \times V_2$	125.28	46.32	52.67	2.74	2.73	17.24	7.95
$Y_2 \times V_3$	118.32	42.90	51.33	2.13	2.03	16.82	7.71
$Y_3 \times V_1$	133.83	47.60	68.44	2.95	2.94	17.49	8.34
$Y_3 \times V_2$	126.00	46.60	69.14	2.57	2.55	15.96	7.43
$Y_3 \times V_3$	119.67	42.50	66.22	1.95	1.90	14.28	6.96
LSD (0.05)	1.34	2.55	2.25	0.14	0.13	0.72	0.35
CV (%)	0.91	4.73	3.06	4.60	4.25	3.61	3.54
LS	**	ns	ns	**	***	*	*

LS = level of significance; ns = non significant at p= 0.05; *significant at p= 0.05; **significant at p= 0.01; ***significant at p= 0.001; Y_1= Year 2013-14, Y_2 = 2014-15; Y_3 = 2015-16; V_1 = BARI Rashun-1, V_2 = BARI Rashun-2 and V_3 = local cultivar

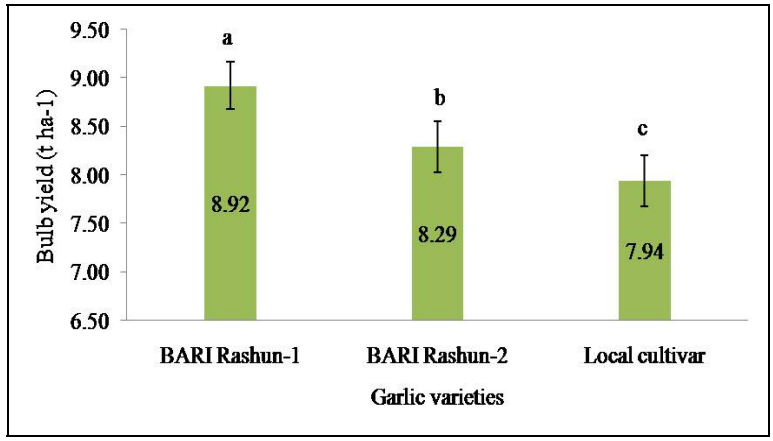

Figure 2 - Bulb yield of garlic due to different tested varieties

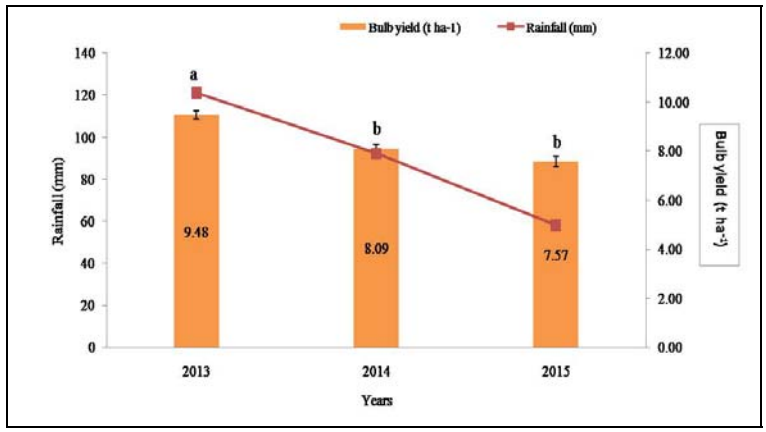

Figure 3 - Bulb yield of garlic in relation to rainfall at different tested years

Correlation study

Correlation coefficient among different characters has been presented in *Table 3*. Bulb yield obtained positive response in all the characters, whereas significant positive correlation showed only with bulb length (0.67*) and individual bulb weight (0.74*). Individual bulb weight showed significant positive correlation almost all the characters except crop duration (0.66) and plant height (r = -0.18). Bulb width showed a strong positive and significant relationship in all the traits, except plant height and bulb yield. Bulb length showed a positive and significant relationship in all the traits, except plant height. Plant height showed positive and insignificant relationship almost entire the study traits, except individual bulb weight where obtained negative association. Except plant height and bulb yield, plant population showed positive and significant relationship in all the study traits. Crop duration showed positive and significant relationship with plant population, bulb length and bulb width, whereas insignificant observed in rest of the traits.

Functional relationship of different yield contributing traits on bulb yield of garlic

The functional linear analysis was performed using the three years pooled data of yield contributing characters along with the bulb yield. From the relationship it was displayed that the studied traits had positive contribution on the bulb yield, which indicated that the bulb yield was dependent on those traits. To evaluate the role of those traits, linear regressions were done. The results exposed that yield contributing characters like crop duration, plant population, plant height, bulb length, bulb width, individual bulb weight accounted for 12, 36, 0.05, 45, 41 and 55% of the total bulb yield variation, respectively (*Fig. 4*).

Table 3 - Correlation among the studies traits

	CD	PP	PH	BL	BW	IBWt	BY
CD	1						
PP	0.87**	1					
PH	0.29	0.36	1				
BL	0.87**	0.95***	0.15	1			
BW	0.89**	0.96***	0.16	0.99***	1		
IBWt	0.66	0.71*	-0.18	0.85**	0.82**	1	
BY	0.35	0.60	0.22	0.67*	0.64	0.74*	1

*significant at = 0.05; **significant at = 0.01; ***significant at = 0.001;
CD = crop duration; PP = plant population; PH = plant height; BL = bulb length;
BW = bulb width; IBWt = individual bulb weight; BY = bulb yield

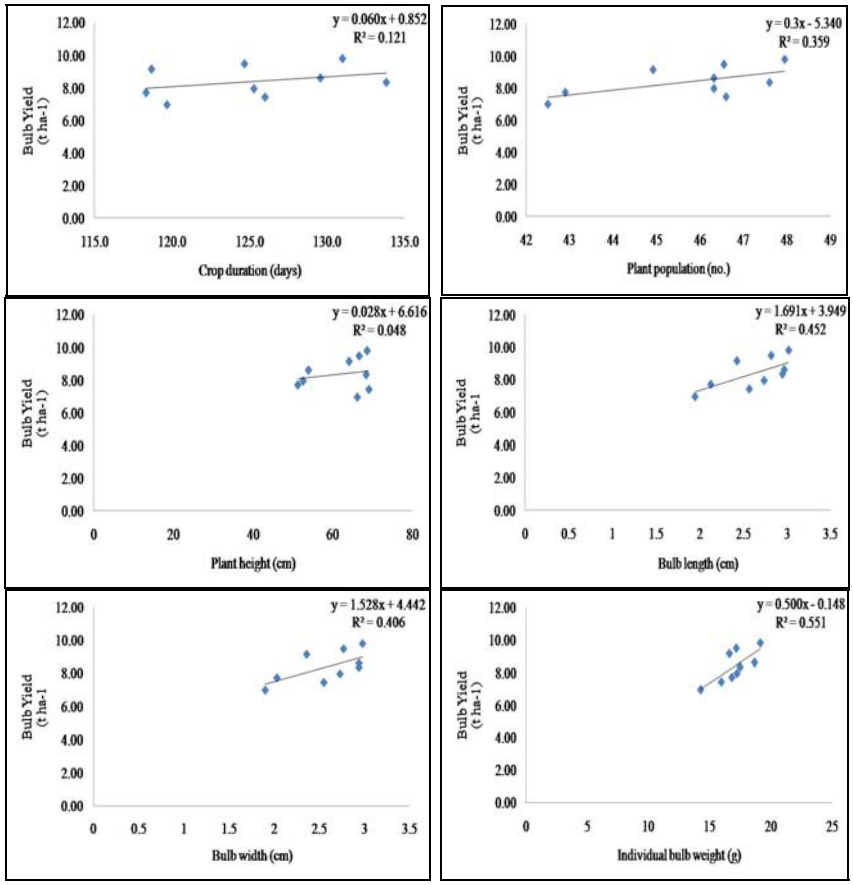

Figure 4 - Relationship of different yield contributing traits (bottom) on bulb yield of garlic

Cost, return and profitability of garlic varieties

Cost is calculated on the basis of total cost (TC) and total variable cost (TVC), which includes labour, land preparation, seed, fertilizer and manure, irrigation, pesticides, interest on operating capital and rental value of land. Three years average cost is presented in *Table 4*. The average TVC of BARI Rashun-1, BARI Rashun-2 and the local cultivar were calculated at Tk. 144275 ha^{-1}, Tk. 143827 ha^{-1} and Tk. 141281 ha^{-1}, respectively, while, TC was Tk. 163025 ha^{-1} for BARI Rashun-1, Tk. 162577 ha^{-1} for BARI Rashun-2, Tk. 160031 ha^{-1} for the local cultivar. Returns from BARI Rashun-1 was the highest (GR: Tk. 363700 ha^{-1}, GM: Tk. 219425 ha^{-1} and NR: Tk. 200675 ha^{-1}) among all other varieties, due to its higher yield, and it was followed by BARI Rashun-2 (GR: Tk. 348210/ha and GM: Tk. 204382/ha and NR: Tk. 185633 ha^{-1}). The least return was in the local cultivar (GR: Tk. 329310 ha^{-1}, GM: Tk. 188029 ha^{-1} and NR: Tk. 169279 ha^{-1}). Benefit cost ratio (BCR) was also the highest in BARI Rashun-1 (2.23), followed by BARI Rashun-2 (2.14) and the local cultivar (2.06). This finding was supported by Khatun *et al.,* (2014).

Table 4 - Cost, return and profitability of different garlic varieties at farmers field (three years average)

Varieties	Gross return (Tk ha^{-1})	Total cost (Tk ha^{-1})	Total variable cost (Tk ha^{-1})	Gross margin (Tk ha^{-1})	Net return (Tk ha^{-1})	Benefit cost ratio (BCR)
BARI Rashun-1	363700	163025	144275	219425	200675	2.23
BARI Rashun-2	348210	162577	143827	204383	185633	2.14
Local cultivar	329310	160031	141281	188029	169279	2.06

Price: garlic as seed: TK 100 kg^{-1}; garlic as consumption: TK 42 kg^{-1}; labour: Tk.250/day/capita

CONCLUSION

Regarding the bulb yield, BARI Rashun-1 appeared as promising in terms of their higher bulb yield potential and more economic return in comparison to existing local cultivar grown successfully in calcareous soil under High Ganges River Floodplain (AEZ-11) in Bangladesh. The variety BARI Rashun-1 had produced the highest plant height, bulb length, bulb width and individual bulb weight under calcareous soil. On account of gross return, gross margin, net return and benefit cost ratio, BARI Rashun-1 variety performed better than other cultivars. So, farmers that have land with calcareous soil could cultivate BARI Rashun-1 variety for higher bulb yield and economic profitability.

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