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Performance Assessment of Various Garlic (*Allium sativum* L.) Germplasm in Bangladesh

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Abstract

Garlic (*Allium sativum* L.) is increasingly becoming an essential component in human diet due to tremendous health-promoting benefits. A total of 25 garlic germplasms have been used in this study from collected various sites in Bangladesh and abroad. The garlic was cultivated in the field laboratory of Horticulture Farm under Bangladesh Agricultural University, Mymensingh, Bangladesh during October/18 to March/19. All germplasm was characterized on number of leaves, height of plant, leaf length, fresh weight of leaf, dry weight of leaf, number of cloves per bulb, length and diameter of bulb, fresh weight of bulb, dry weight of bulb, yield per plot and yield per hectare. Analyses of variances showed that garlic germplasm with different origins was significantly different for all characters. Germplasm G49 from Vietnam showed the highest results in respect of number of leaves per plant (10.63), leaf length (43.57 cm), fresh leaf weight (92.47g), dry leaf weight (6.13g), fresh weight of bulb (21.37g), total number of cloves per bulb (42.13), bulb diameter (4.13cm), fresh weight of bulb (21.37g), dry weight of bulb (5.73g) and yield (9.83 t/ha) which could help future researchers in garlic selection program and improvement of yield.

Keywords: Physiology, performances, germplasm and garlic.

Introduction

Allium sativum, commonly known as garlic, is a species of the onion family Alliaceae (Allen, 2009). The origin of garlic is thought to be in Central Asia (India, Afghanistan, West China, Russia) and spread to other parts of the world through trade and colonization (Tindal, 1986). Its close relatives include the onion, shallot and leek. It is the second most widely used spice crop of the cultivated Allium crops, next to onion in the world (Purseglove, 1975). Its primary center of origin is Central Asia (Kazakhstan),

and the secondary center is the Mediterranean and Caucasus zones. The area under garlic cultivation in Bangladesh is only 2452 thousand hectares and the production is 346 metric tons (BBS, 2014). Garlic is important for its culinary and medicinal importance throughout the world. The cloves are used for consumption (raw or cooked), or medicinal purposes, and have a characteristic pungent, spicy flavor that mellows and sweetens considerably with cooking. Today garlic is used to help in preventing heart disease, including atherosclerosis (plaque buildup in the arteries that can block the flow of blood and possibly lead to heart attack or stroke), high cholesterol, high blood pressure, and to improve the immune system (Kilgori *et al.*, 2007). The oil of garlic is volatile and has sulfur combining compounds responsible for strong odor, its unique flavor and pungency, and healthful benefits (Salomon, 2002). Garlic is a basic flavoring in many dishes, ranging from vegetable soup, meat, salad, tomato combination, spaghetti, sausages, and pickles (Brewster, 1994). Bread and butter obtained from garlic have many uses in homes and restaurant cooking and food preparations (Nonnecke, 1989). Garlic may also protect against cancer. The world average yield of garlic is 26.6 million of tons (FAO, 2016). On the other hand, the yield in Bangladesh is only 3.8 million of tons (FAO, 2016), which is very low compared to the yield of many other countries. In Bangladesh, the requirement of garlic is about 219 thousand metric tons, and the deficit is around 42 thousand metric tons. In spite of high demand, Bangladesh is not in a position to supply and fulfill the actual demand for garlic. The major reasons behind this are lack of suitable genotypes, lack of land, use of local unimproved varieties, environmental stress, poor crop management, proper research and lack of knowledge about the morphological characteristics of garlic germplasm. A good number of landraces of garlic are present in Bangladesh. But till now, few recommended or released varieties are available. Systematic research was not conducted in the past to evaluate potentialities of the available garlic germplasm. Knowledge about the morphological characteristics of garlic germplasm is most important for selection of the appropriate varieties for appropriate place and achievement of high yield. Besides, characterization is an important aspect for documentation of the studied cultivars' performance, which will subsequently help introduce, select, and improve the existing varieties. The present experiment has been taken to determine the morphological characteristics of 25 garlic germplasm and to evaluate the comparative performance of the selected germplasm.

Materials and Methods

The research work was done in the rabi season during October 2018 to March 2019 at the Allium Field Laboratory, Horticulture Farm, Bangladesh Agricultural University, Mymensingh. Twenty-five germplasm of garlic were collected from different parts of Bangladesh (Nilphamari, Dinajpur, Ishurdi, Magura, Rajshahi and Mymensingh district) also different parts of the world (Tunisia, Turkey, Florida, China and Vietnam). The details of germplasm are listed in Table 1.

Design and layout of the experiment

The experiment was laid out in a Randomized Completely Block Design (RCBD) with three replications. The whole plot was divided into three blocks, each containing 25 unit plots of 1 square meter and one germplasm represented one treatment.

Climate and Soil condition

The experimental area was under a sub-tropical humid climate which is characterized by heavy rainfall, air temperature, sunshine hour, annual average rainfall and relative humidity. The soil of the experimental area of Bangladesh Agricultural University Farm was sandy loam and belongs to the Old-Brahmaputra Flood-Plain Alluvial Tract (UNDP, 1988). The soil samples collected at a depth of 0-30 cm from the, experimental area were analyzed in the Humboldt Soil Testing Laboratory, Department of Soil Science, Bangladesh Agricultural University, Mymensingh. The morphological characteristics of the soil of the experimental plot are given below-

AEZ: Old Brahmaptura Flood Plain; Soil series: Sonatala series; General soil: Non calcareous dark grey and Parent material: Old Brahmaptura River-borne deposits.

Cultural management

Land preparation: The experimental land was first opened by tractor one month before planting. Several ploughing and cross ploughing followed by laddering were done until the desired tilth was achieved for planting the cloves. Weeds and stubbles were then removed from the field. Finally, the land was divided into blocks in which small plots (plot size were mentioned in individual experiment) were made

Table 1. List of 25 garlic germplasm used in the study

Sl. No.	Germplasm	Local Name	Collected from
1	G1	BAU Garlic - 1	BAU- Mymensing
2	G2	BAU Garlic - 2	BAU- Mymensing
3	G3	Baserhati	Baserhat, Dinajpur
4	G5	Lal Shil	Domar, Nilphamari
5	G8	Mahakunda	Dadpur, Pabna
6	G10	Sada shil	Sadar, Nilphamari
7	G13	Lal Shil	Dimla, Nilphamari
8	G15	Sutna	Mohonpur, Rajshahi
9	G19	BAU Selection-1	BAU- Mymensing
10	G20	Sada shil	Debigonj, Panchagarh
11	G27	Florida -1	Florida, USA
12	G28	Florida -2	Florida, USA
13	G29	Turkey-1	Turkey
14	G30	Turkey -2	Turkey
15	G31	Tunisia -1	Tunisia
16	G32	Tunisia -2	Tunisia
17	G33	Tunisia -3	Tunisia
18	G35	China -1	China
19	G36	China -2	China
20	G37	China -3	China
21	G38	China -4	China
22	G49	Vietnam-2009	Vietnam
23	G51	Putia-10	Putia, Rajshahi
24	G52	China -10	China
25	G53	Vietnam-2010	Vietnam

as an experimental unit according to the design of the experiment.

Manure and fertilizer: The crop received manures and fertilizers at the rate of cowdung 5 tons, Urea 217 kg, T.S.P. 267 kg, M.P. 333 kg and Zypsum 111 kg per hectare respectively. The entire amount of cowdung and TSP were added to the soil at the time of final land preparation 7 days before planting. Urea and MP were top dressed in three equal installments at 25, 50 and 75 days after planting of cloves or transplanting of seedlings.

Planting materials: Cloves were separated from the bulb, and only the healthy large sized ones were planted. Date of planting was 10 Nov, 2015 and plant spacing was 20 cm x 10 cm.

Intercultural operation: Weeding and pulverizing of soil were done regularly whenever necessary to keep the plots free from weeds and to ensure good aeration in soil. Ridomil MZ 72 WP and Rovral at the rate of 25g and 45g in 10 litre of water was applied at an interval of 15 days from 30 DAP up to one month before harvesting to prevent the purple leaf blotch disease caused by Alternaria porii. The garlic plants when the tops turn yellowish or light brownish and show signs of drying up indicate the symptom of maturity. The bulbs were lifted, freed from earth and the leaves were tied at the top. The bulbs were cured for 2 to 3 days in the shade before storing them in an ordinary room. Thoroughly cured garlic bulbs store well in ordinary well-ventilated room/store. At the experimental site, a laboratory for weighing and sample drying was used. A good electrical weighing balance and oven were used.

Collection of data

The following data were recorded on the base of physio- morphological growth parameters after planting as well as on yield. The number of leaves per plant was counted from 5 randomly selected plants. The mean number of leaves was calculated by dividing total number of leaves observed from 5 plants by 5. Plant height was measured from the base of the leaf sheath to the tip of the longest leaf of 5 randomly selected plants and mean was calculated in cm. Length of leaf was measured from the base to top of the leaf of 5 randomly selected leaves in centimeter and mean was calculated. Fresh weight of leaves of 5 randomly selected plants was taken and their average was calculated in gram as fresh weight of leaves of individual plant. Fresh weight of leaves of 5 randomly selected plants was taken and the average was considered in gram as fresh weight of leaves per plant. The leaves were cut into small pieces, dried in the sun for 3 days and kept in an oven at 80°C for 72 hours, till a constant weight was achieved. Average dry weight of leaves per five plants was estimated. The cloves were counted from 5 plants and their average was taken as a number of cloves per plant. Diameter at the widest part of 5 randomly selected bulbs was measured in centimeter and then average diameter of each bulb was calculated. Fresh weight of bulb of 5 randomly selected plants was taken and their average was calculated in gram as fresh weight of bulb of individual plant. Fresh weight of bulb of 5 randomly selected plants was taken, and the average was considered in gram as fresh weight

Table 2. Morphological characters of different garlic germplasm.

Treatment	Number of leaves per plant	Plant height (cm)	Leaf length (cm)	Fresh weight of leaf (g)	Dry weight of leaf (g)
G1	6.37	66.17	39.23	24.27	3.27
G2	6.60	66.50	40.17	25.20	3.70
G3	5.53	62.17	40.37	27.23	3.53
G5	7.03	65.47	37.07	23.47	3.47
G8	4.70	62.80	39.63	67.80	4.30
G10	5.03	66.47	23.97	25.87	2.57
G13	5.43	39.17	27.60	22.63	2.93
G15	5.73	52.40	40.70	25.93	4.40
G19	6.17	65.77	36.20	47.57	4.00
G20	5.50	62.30	35.53	25.37	3.47
G27	7.43	55.90	38.03	32.60	3.70
G28	5.93	74.60	40.30	31.37	2.77
G29	6.93	62.50	41.27	21.73	5.53
G30	5.97	58.63	36.90	28.63	5.40
G31	5.93	52.93	31.37	30.70	3.03
G32	5.40	60.40	31.83	21.17	2.60
G33	6.27	53.47	35.30	22.57	2.80
G35	5.20	65.70	36.60	38.43	3.70
G36	7.10	64.77	37.43	32.40	3.23
G37	5.63	57.57	32.37	21.63	4.50
G38	5.90	48.93	26.63	85.50	4.17
G49	10.63	65.53	43.57	92.47	6.13
G51	6.37	51.50	35.53	78.93	5.43
G52	5.93	54.20	33.93	61.43	5.53
G53	7.43	60.43	39.20	74.73	5.60
LSD 5%	**1.08**	**1.23**	**0.94**	**0.97**	**0.92**
LSD 1%	**1.44**	**1.64**	**1.26**	**1.30**	**1.22**
Level of significance	**	**	**	**	**

** = Significant at 1% level of probability, G1-G53 are the garlic germplasm.

of bulb per plant. Bulbs were cut into small pieces, dried in the sun for 3 days and kept in an oven at 80°C for 72 hours, till a constant weight was achieved. Average dry weight of bulb per plant was estimated. The yield of bulb per plot was taken in kilogram (kg) by harvesting all the bulbs of each plot after removing the roots and pseudo stem. Per plot yield of bulb was converted into yield per hectare and expressed in ton (t).

Statistical analysis

Data collected from the experiment were statistically analyzed as per design of the experiment followed in the field using PLABSTAT computer package programmer. The means for all treatments were calculated and the analyses of variances for all the characters under consideration were performed by 'F' variance test. The significance of difference between pair of means was performed by Least Significant Difference (LSD) test taking 5% probability level as the minimum unit of significance (Gomez and Gomez, 1984).

Estimation of simple correlation coefficients:

Simple correlation coefficients were calculated using PLABSTAT software version 2N (Utz 2007) by the following formula-

$$r = \frac{\sum xy - \frac{\sum x \sum y}{N}}{\sqrt{\left\{x^2 - \frac{(x)^2}{N}\right\}\left\{y^2 - \frac{y^2}{N}\right\}}}$$

Where, $\sum$ = Summations, X and Y two variables correlated and N = Number of observation.

Results and Discussion

A wide range of variation was observed among germplasm on number of leaves, height of plant, leaf length, number of cloves per bulb, length and

Table 3. Yield and yield contributing characters of different garlic germplasm.

Treatment	Number of cloves/plant	Bulb diameter (cm)	Fresh weight of bulb (g)	Dry weight of bulb (g)	Yield (kg/plot)	Yield (t/ha)
G1	25.97	3.70	15.80	4.33	0.671	6.71
G2	22.83	3.40	14.53	3.47	0.658	6.58
G3	20.70	3.83	15.60	4.10	0.617	6.17
G5	21.77	3.53	13.57	3.13	0.571	5.71
G8	21.27	3.43	14.77	3.80	0.635	6.35
G10	25.63	3.37	14.50	3.30	0.563	5.63
G13	26.23	3.50	13.43	3.37	0.524	5.24
G15	22.30	3.60	13.53	3.13	0.582	5.82
G19	27.03	3.60	12.93	3.27	0.584	5.84
G20	21.40	3.47	12.70	3.33	0.550	5.50
G27	26.20	3.53	15.77	5.10	0.754	7.54
G28	22.40	3.33	13.23	3.27	0.598	5.98
G29	23.13	3.37	14.40	3.70	0.581	5.81
G30	20.70	3.47	13.53	3.30	0.621	6.21
G31	20.83	3.07	12.97	3.57	0.576	5.76
G32	21.57	3.37	14.57	3.77	0.632	6.32
G33	22.10	3.40	13.60	3.27	0.584	5.84
G35	18.27	3.07	12.93	3.27	0.594	5.94
G36	17.57	3.03	13.23	3.37	0.567	5.67
G37	23.57	3.50	13.87	3.87	0.665	6.65
G38	25.53	2.73	11.83	2.87	0.552	5.52
G49	42.13	4.13	21.37	5.73	0.983	9.83
G51	27.37	3.40	12.53	3.13	0.574	5.74
G52	18.20	3.27	13.43	2.93	0.631	6.31
G53	19.43	3.87	18.23	4.43	0.832	8.32
LSD 5%	1.11	1.03	1.27	0.68	0.01	0.18
LSD 1%	1.47	1.38	1.69	0.91	0.02	0.24
Level of significance	**	**	**	**	**	**

** = Significant at 1% level of probability, 1 Plot size = $1m^2$

diameter of bulb, yield per plot and yield of garlic during the growth period as well as at final harvest.

Morphological characters of different garlic germplasm: There were significant differences in the number of leaves per plant. The highest number of leaves (10.63) was obtained from germplasm G49. On the other hand, the lowest number of leaves (4.70) was recorded from germplasm G8 followed by G10 (5.03), G35 (5.20) and G32 (5.40). It was observed that germplasm G29 produced the tallest plant (74.60 cm) followed by G2 (66.50cm) and G1 (66.17cm). The shortest plant was found in the germplasm G13 (39.17 cm). Significant differences were also observed in length of leaf. The highest length of leaves (43.57cm) was obtained from germplasm G49 followed by G29 (41.27cm). On the other hand, the lowest length of leaves (23.97 cm) was recorded from germplasm G10 followed by G38 (26.63 cm) and G13 (27.60 cm).

Remarkable variations were observed on fresh leaf weight. The highest fresh leaf weight (92.47) was obtained from germplasm G49 followed by G38 (85.50), G53 (74.73) and G8 (67.80) gm. On the other hand, the lowest fresh leaf weight (21.17) was recorded from germplasm G32. Germplasm G49 produced the highest amount of dry leaf weight (6.13g). The lowest amount of dry leaf weight was found in germplasm G10 (2.57g) (Table 2).

Yield and yield contributing characters of different garlic germplasm

Number of cloves showed per plant significant differences among them. The highest number of cloves (42.13) was recorded from germplasm G49. On the other hand, the lowest number of cloves was observed from G36 (17.57). Highly significant differences were observed in bulb diameter also. Among bulb diameters G49 (4.13 cm) was recorded

Table 4. Coefficients of correlation for morphological characters of different garlic germplasm

Characters	Number of leaves per plant	Plant height (cm)	Leaf length (cm)	Fresh weight of leaf (g)
Plant height (cm)	0.171			
Leaf length (cm)	0.489*	0.48*		
Fresh weight of leaf (g)	0.406*	-.112	0.084	
Dry weight of leaf (g)	0.460*	-0.150	0.322	0.689**

* Significant at 5% level of probability,
** Significant at 1% level of probability

the highest. On the other hand, G38 (2.73 cm) performed the lowest. It was observed that germplasm G49 produced the highest amount of fresh weight of bulb (21.37 g) and the lowest amount of fresh weight of bulb was found in germplasm G38 (11.83 g) followed by G51 (12.53 g) and G20 (12.70g). Maximum dry weight of bulb was obtained from G49 (5.73 g) which was significantly different from others and followed by G27 (5.10 g). Minimum dry weight of bulb was obtained from G38 (2.87 g) followed by G52 (2.93 g). Highly significant differences were observed in yield of bulb per plot. The germplasm G49 (0.983 kg) produced highest yield per plot whereas the lowest (0.524 kg) was from G13. The yield of garlic per plot was converted into per hectare and was expressed in tons. Yield per hectare of different germplasm showed highly significant variations. Germplasm G49 gave the highest (9.83 t/ha) yield followed by germplasm G53 (8.32 t/ha). The lowest yield (5.24 t/ha) was obtained from germplasm G13 (Table 3).

Different germplasm resulted better performance in respect of height of plant, number of leaves per plant, fresh weight of bulb, total number of cloves per bulb and yield in ton per hectare. Germplasm G49 from Vietnam gave the highest results in almost all the mentioned parameters. This might be due to the fact that germplasm G49 had a good genetic potential which enhanced more cell division and cell elongation resulting the best performance. (Shigwedha *et al.* 2009) reported that the maximum plant height (60.47 cm), maximum yield per plot (7.57 kg) and the maximum number of leaves per plant (14.60). (Gupta *et al.*2003) found in their research the greatest bulb diameter (3.26 and 3.23 cm). (Avila, 2000) also reported about the bulb diameter which varied from 66 to 70 cm. These investigations are more or less supportive of the present findings.

Coefficients of correlation for morphological characters

The estimated simple correlation coefficients were made among different morphological characteristics of garlic germplasm in all possible one-way paired combinations. Number of leaves per plant was not significantly and positively correlated with plant height (r = 0.171). Whereas leaf length (r = 0.489*), fresh weight of leaf (r = 0.406*) and dry weight of leaf (r = 0.460*) showed significant positive correlation. Plant height showed significant positive correlation with leaf length (r = 0.480*). On the other hand, fresh weight of leaf (r = -0.112) and dry weight of leaf (r = -0.150) showed non-significant negative correlation. Leaf length was not significantly and positively correlated with fresh weight of leaf (r = 0.084) and dry leaf weight (r = 0.322). Fresh weight of leaf showed highly significant positive correlation with dry weight of leaf (r = 0.689**) which indicated that with the increase of fresh weight of leaf those dry weight of leaf would be increased (Table 4).

Table 5. Coefficients of correlation for yield and yield contributing characters of different garlic germplasm

Characters	Number of cloves/plant	Bulb diameter (cm)	Fresh weight of bulb (g)	Dry weight of bulb (g)	Yield (kg/plot)
Bulb diameter (cm)	0.539**				
Fresh weight of bulb (g)	0.567**	0.785**			
Dry weight of bulb (g)	0.574**	0.685**	0.896**		
Yield (kg/plot)	0.554**	0.679**	0.926**	0.875**	
Yield (ton/ha)	0.554**	0.679**	0.926**	0.875**	1.000**

** Significant at 1% level of probability

Coefficients of correlation for yield and yield contributing characters of different garlic germplasm

Highly significant positive correlation was observed

in number of cloves per plant with bulb diameter (r = 0.539**), fresh weight of bulb (r = 0.567**), dry weight of bulb (r = 0.574**), yield per plot (r = 0.554**) and yield per hector (r = 0.554**) which indicated that with the increase in number cloves per plant those bulb diameter, fresh weight of bulb, dry weight of bulb, yield per plot and yield per hectare would be increased. Bulb diameter also showed highly significant positive correlation with fresh weight of bulb (r = 0.785**), dry weight of bulb (r = 0.685**), yield per plot (r = 0.679**) and yield per hectare (r = 0.679**). Fresh weight of bulb showed highly significant and positive correlation with dry weight of bulb (r = 0.896**), yield per plot (r = 0.926**) and yield per hectare (r = 0.926**). A highly significant positive correlation was observed in the dry weight of bulb with yield per plot (r = 0.875**) and yield per hectare (r = 0.875**), which indicated that the increase in dry weight of bulb those yield per plot and yield per hectare would be increased. Yield of bulb per plot showed a highly significant and positive correlation with yield per hectare (r = 1.000**) that means increasing yield per plot with the increasing yield per hectare (Table 5).

Conclusion

Among germplasm on number of leaves, height of plant, leaf length, number of cloves per bulb, length and diameter of bulb, yield per plot and yield of garlic during the growth period as well as at final harvest variation was observed. There were significant differences in the number of leaves per plant. The highest number of leaves (10.63) was obtained from germplasm G49. On the other hand, the lowest number of leaves (4.70) was recorded from germplasm G8 followed by G10 (5.03), G35 (5.20) and G32 (5.40). The highest number of cloves (42.13) was recorded from germplasm G49. On the other hand, the lowest number of cloves was observed from G36 (17.57). These investigations are more or less supportive of the present findings.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relations that could be constructed as a potential conflict of interest.

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